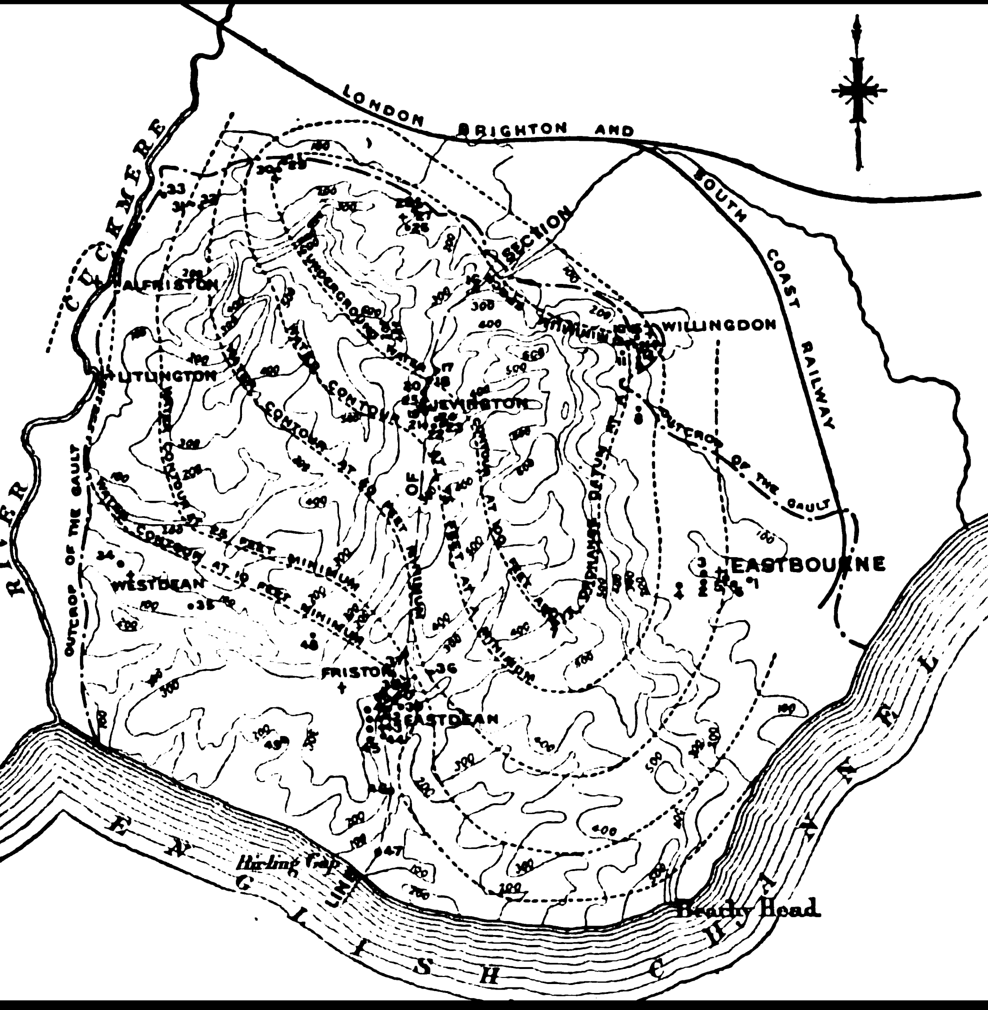

Minutes of proceedings of the Institution of Civil Engineers

Institution of Civil Engineers (Great Britain)

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

49460

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CXLII.

EDITED BY

J. H. T. TUDSBERY, D.Sc., M. Inst. C.E., Secretary.

LONDON:
Published by the Institution,
GREAT GEORGE STREET, WESTMINSTER, S.W.
[Telegrams, "Institution, London." Telephone, "Westminster, 51."]
1900.

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LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS

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CORRIGENDA.

Vol. cxxxiv. p. 295, line 25, *for* "divided by" *read* "divided into."

" " p. 299. In diagrams 5 and 6 the number of revolutions should be transposed so as to read "480" for Fig. 5 and "195" for Fig. 6.

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1899-1900.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

20 March, 1900.

CHARLES HAWKSLEY, Vice-President,
in the Chair.

(*Paper No. 3227.*)

"The Great Central Railway Extension: Northern Division."

By FREDERICK WILLIAM BIDDER, M. Inst. C.E.

IN this Paper the Author proposes to describe generally the works upon the line, indicating particularly points where variations from ordinary practice may have occurred in details, railway construction being now so well understood in this country.

For many years the Manchester, Sheffield and Lincolnshire Railway Company had desired independent access to the Metropolis, and as long ago as 1873 they promoted, in conjunction with the Midland Railway Company, a Bill for the construction of a series of joint lines, with the object of securing access to St. Pancras Station. This Bill was strongly opposed by the Great Northern Railway Company, and so much of the scheme was rejected as to render it inadvisable to proceed with the remainder.

In 1888 the Company made their first attempt to acquire independent powers for the extension of their line in a southerly direction from Beighton, near Sheffield, to Chesterfield. This Bill was thrown out, however, owing to the opposition of the Midland Railway Company. In the following session a Bill was deposited for a more comprehensive scheme, viz., a line from Beighton to Annesley, passing through Staveley, with a branch to Chesterfield, the intention being to form a junction at Annesley with the Great Northern Leen Valley line about 9 miles to the north of Nottingham. After considerable opposition the Bill was passed, the work of construction was proceeded with, and this portion of the extension southwards, which passes through the heart of the Derbyshire coalfields, was opened for traffic in 1892.

In the meantime the late Mr. Charles Liddell, who was the Engineer for this portion of the railway, had, in conjunction with Mr. Edward Richards and Mr. Edward Parry, M. Inst. C.E., prepared the Parliamentary plans and estimates for an extension to London, comprising (1) a line from Annesley to Quainton Road, a distance of about 92 miles, at which latter point it was proposed to form a junction with the Aylesbury and Buckingham Railway, now a part of the Metropolitan Railway; (2) a widening of the Metropolitan Company's line from Willesden Green to Finchley Road; and (3) a short line from the West Hampstead Station of that company to the proposed terminus at Boscobel Gardens, Marylebone. A Bill for the complete scheme was brought before Parliament in the session of 1891, but after a severe contest it was rejected. In the following session an amended scheme was deposited, various alterations and improvements, including the extension of the London portion to Marylebone Road, being made to avoid opposition, which, however, was again so strong that the Bill was passed only after a prolonged struggle. Owing to the dissolution of Parliament the Royal assent was not obtained until the end of March, 1893. After the passing of the Act some time was occupied in preparing the contract plans and sections for the new line, but owing to arrangements for raising the capital being incomplete this work was suspended for several months, in consequence of which the contracts were not let until September, 1894.

The first sod was cut on the 13th November of the same year, from which date the work of construction proceeded without intermission, the line being sufficiently completed by July, 1898, to allow of the running of coal trains. It was formally opened for passenger traffic on the 9th March, 1899, the company in the meantime having changed its name from the Manchester, Sheffield and Lincolnshire to that of the Great Central Railway, as a more suitable title to their extended system. For engineering purposes the line was divided, Mr. Edward Parry being appointed Engineer for the northern division, and Sir Douglas and Mr. Francis Fox for the southern and metropolitan divisions.

The northern division commences at a junction with the Derbyshire line of the Company near Annesley, and runs in a southerly direction through Nottingham, Loughborough, and Leicester to the Oxford Canal near Rugby, the total distance being 51 miles 69 chains (Figs. 1, Plate 1).

There are in all sixteen passenger stations upon this division, the most important being the Central Station at Nottingham and the stations at Leicester and Loughborough. Of the others, eleven are of the ordinary country station type adopted for the line, with

island platforms, which had been settled by Mr. Alexander Ross, M. Inst. C.E., formerly Chief Engineer of the Company, with the necessary variations to suit local requirements. The remaining two, at Carrington and Arkwright Street, Nottingham, have, owing to their positions, the usual double platforms, but, unlike the others, are without accommodation for goods traffic. Large goods yards have been laid out at Nottingham, Loughborough, and Leicester, and extensive sorting sidings have been provided at Annesley. For the locomotive and carriage and wagon departments accommodation has been provided at Annesley, New Basford, Nottingham, and Leicester.

The gradients are good, the steepest being 1 in 130 north of Nottingham and, with the exception of two short lengths, 1 in 176 south of Nottingham. The line has been laid out with very easy curves, the usual minimum radius of 1 mile being only departed from in two cases, on the Nottingham and Leicester viaducts in approaching the stations, where curves of 20 chains and 40 chains radius could not well be avoided. Between Annesley and Nottingham the cuttings are in the magnesian limestone and bunter sandstone. South of Nottingham they are for some distance in the keuper marl, rhaetic shale being met with near East Leake. Beyond this point many of the cuttings are in the boulder clay, and south of Leicester they are chiefly in the red marl, boulder clay, and the blue clays of the lower lias.

The total quantity of excavation amounts to over 6,000,000 cubic yards, but no great difficulty was experienced in dealing with the earth-works, every precaution being taken to secure sufficient drainage. Several slips of minor importance have occurred on the embankments, due chiefly to the heavy rains following the remarkably dry weather during which the banks had been tipped. Where necessary, a heading drain was specified to be laid on the high side of the line, with which all intercepted land drains were to be connected before the excavation was commenced in cuttings. The general form of drainage adopted in the slopes of cuttings and embankments is very similar in appearance to the piers and arches of a viaduct, the vertical drains formed of hand-packed stone being connected at the top by a series of arched drains formed of the same material. The lower ends of these drains are connected with the formation drains, which consist of 6-inch earthenware pipes laid in trenches filled with broken stone. Brick catchpits with York stone covers are constructed upon the formation drains, at distances of 5 chains apart.

The formation width adopted for cuttings is 28 feet, and for

embankments 31 feet. North of Leicester the slopes of embankments and cuttings are generally 1½ to 1, except in rock where the batter is ½ to 1. South of Leicester the slopes are chiefly 2 to 1, except in the case of high embankments where the lower portion is formed 3 to 1. The longest embankment is that at Whetstone, which extends for a distance of 3 miles, and contains 818,000 cubic yards of material. One of the largest cuttings, from which 330,000 cubic yards of earth were taken, is through the Normanton Hills, near Loughborough, and is ⅝ mile in length and 52 feet deep. Broken stone, hand-pitched 9 inches in depth, forms the bottom ballast, upon which, after being covered with 3 inches of fine gravel or granite chippings, the permanent way is laid, the top ballast being of gravel or granite chippings.

The permanent way consists of 86-lb. rails, in lengths of 30 feet, with eleven sleepers, 10 inches by 5 inches, to each length, the cast-iron chairs, weighing 52 lbs., being secured to the sleepers by two iron spikes and two trenails to each. In certain portions of the sidings, where the wear and tear of the traffic is not so great, a lighter section of rail has been used, weighing 75 lbs. per yard, with chairs weighing 38 lbs. each. Upon all the more important bridges and viaducts, rail-guards have been provided on both sides of each line, a special cast-iron chair having been designed for this purpose, which not only holds the running rail in the usual way, but supports a second rail laid on its side and bolted to the top of a projecting bracket carried up a little above the level of the running rail (Figs. 12, Plate 2). These chairs weigh 93 lbs. each, and are secured to 12-inch by 6-inch timbers, in the same manner as the ordinary chairs; and as both the rails and guard-rails are fixed to the same chairs, any lifting or slewing of the road does not affect their relative positions. Old rails, weighing about 65 lbs. per yard, are used for the guard-rails, the joints being fished with one plate only, on the lower side; and the rails are fastened to the chairs by two ⅞-inch bolts to each chair. In each length of guard-rail two holes are drilled through the web for drainage.

There are in all five tunnels, having a total length of 2,430 yards, and eleven viaducts, covering altogether about 3,400 yards. The bridges are varied in character, and number no less than 224, of which 155 have steel superstructures. Wherever practicable, brick arches have been adopted in preference to girder spans, both for underbridges and overbridges.

The brickwork throughout is built in Old English bond with common brick, faced with Staffordshire brindle bricks. Except in one or two special cases, all the arches are built in lias lime

mortar, the first two rings being laid in Old English bond and the remaining rings bonded where the courses correspond. The coping to bridges and viaducts consists of specially moulded Staffordshire blue bricks. Girder-beds, arch-springers, newel and pilaster caps, &c., are of Derbyshire gritstone.

Mild steel is used throughout for all girder-work in bridges, buildings and platform-roofing, cast-iron being used only for girder-bearings, base-mouldings, corbels, small roof-columns, &c. The total quantity of iron and steel used upon the northern division exceeds 20,000 tons. The steel used was required to have an ultimate tensile strength of 27 tons to 30 tons per square inch, with an extension of not less than 20 per cent. in a length of 10 inches, the working stress allowed being 5 tons per square inch. The rolling loads adopted for calculating the strength of main girders of underbridges vary for spans between 10 feet and 80 feet, being 4 tons per foot run of single line in the former, and 1·82 ton in the latter case. For larger spans 1·82 ton per foot was allowed up to 100 feet, but beyond this the load was gradually reduced, and for spans of 170 feet, 1·6 ton per foot was provided for. For cross girders, rail-bearers, and all other calculations the maximum load on a pair of wheels was taken at 20 tons.

Where the headway permits, main girders of underbridges are placed directly beneath the rails, and the flooring consists of plates, either flat or slightly curved. For spans where the headway was limited, three main girders were adopted, with cross girders between, except in the colliery district where two centre girders were used instead of one, the halves of the bridge being separate structures, which allows each half to be dealt with independently, in case of settlement of the abutments. For large spans with limited headway the construction consists of two main girders with cross girders, rail-bearers, and plate flooring, this type with plate-web girders having been used for spans up to 80 feet. For larger spans open-web main girders have been preferred, with bracing composed of vertical struts and diagonal bars, the cross girders being suspended from the lower ends of the vertical struts. The expansion-bearings used consist either of turned steel rollers working between cast-iron plates or plain cast-iron sliding plates. The rollers are boxed in all round, and the spaces between the rollers were completely filled up with tallow before the upper plates were placed in position, to exclude dust and moisture.

With the exception of one or two small spans over occupation roads, all the bridges carry the ordinary permanent way on cross-sleepers and ballast, the exceptions being instances of limited

headway where it was found necessary to adopt trough girders and longitudinal timbers. The overbridges vary considerably in construction, the type preferred and most generally used for spans up to 30 feet consisting of girders and jack arches; but in larger spans various forms of steel flooring take the place of the jack arching. The moving load provided for on road bridges is 2 cwt. per superficial foot.

DESCRIPTION OF THE WORKS.

At the commencement of the line the Annesley sorting-sidings, Fig. 2, Plate 1, which occupy about 60 acres of land lying between the Great Central and Great Northern railways, extend for a distance of 1¼ mile from Annesley Junction, and have been laid down for the purpose of sorting and marshalling by gravitation the traffic brought from the various collieries, etc., in Derbyshire and South Yorkshire for conveyance to London and other places over the new line. A goods loop runs along the middle of the yard between the up and down sidings on a gradient of 1 in 120, the ground having a natural fall towards the south. The reception- and departure-sidings are on inclinations of 1 in 80 and 1 in 132 respectively. The sidings already laid down will accommodate about 1,700 wagons, and large areas are available for further extensions as required. The total length of the various lines and sidings at present in use is nearly 17 miles. A large repairing shop has been erected capable of holding fifty wagons, fitted with all the necessary machinery and appliances for dealing with this work. At the south end is the locomotive yard and running-shed, giving accommodation for thirty engines, with coal-sidings and storage-ground adjoining. Electricity is used for lighting-purposes, the engines, boilers and dynamos occupying a building near the middle of the yard.

Leaving Annesley, the line passes down the Leen Valley to the village of Linby, there crossing two large bridges, one over the Great Northern Leen Valley line and the other over the Midland line to Mansfield. These bridges had to be so constructed as to provide for possible widenings by the respective companies, and each has three steel girder spans, the piers and abutments being of brick. Over the Great Northern line the spans are 47 feet, 78 feet and 26 feet 6 inches, the main girders being placed directly under each of the rails and braced together in pairs. The bridge over the Midland line consists of two spans of 61 feet and one of 23 feet.

From Linby the line proceeds to Hucknall Torkard, a colliery town of some importance, where one station, similar to the ordinary

type of country station adopted for the line, has been constructed; and plans for another to be situated about a mile distant have been prepared. North of the present station there is a deep cutting through magnesian limestone spanned by two large occupation road bridges 36 feet and 50 feet wide respectively, with spans of 60 feet. At the south end of the station a number of sidings have been laid down, connected by a short branch line with the Hucknall Colliery. The bridges upon this portion of the line have all steel superstructures; and hoop iron is built into the abutments and wing-walls owing to the proximity of the coal-workings, except in the case of the Bulwell Viaduct, where the coal for a width of 4 chains on either side of the line was purchased by the Company to avoid any settlement in the ground upon which the viaduct has been built.

In one instance the abutments of a bridge of 12 feet span over an occupation road and the embankments adjoining have sunk about 3 feet since they were completed, but without showing the least sign of settlement, the girders having been raised several times and new brickwork put in to bring the bearings to their proper level. The girders in this case have steel brackets riveted to their under sides near the ends, to prevent any forward movement in the abutments during settlement; and as the latter are rather high, steel struts have been introduced between them at some distance below the main girders.

The Bulwell Viaduct, Fig. 6, Plate 2, which crosses the River Leen and the Midland Railway, is built principally of brick, with one girder span over the Hucknall Road, which is crossed at an angle of 38° 23′. The total length is about 400 yards, and the greatest height from the ground to the rails is 48 feet. The rails are on a gradient of 1 in 130 throughout, and the centre line of the viaduct is straight except for a short distance at the north end, where it is on a curve of 80 chains radius. There are in all twenty-five arches, those crossing the Midland Railway and public road at the south end being on the skew. The square spans are each 34 feet 3 inches, the odd dimension being adopted to suit the distance between the Hucknall Road and the Midland Railway. The arches have a rise of 14 feet 6 inches, the thickness at the crown being 2 feet 3 inches, increased to 2 feet 7½ inches at the haunches. The intermediate piers are 5 feet 3 inches at the arch-springing and have a batter of 1 in 32. The spandril filling of concrete between the side and centre walls is paved with common bricks laid flat and covered with alternate layers of asphalt and canvas, with a fall towards the centre of the piers, upon each of

which is an artificial stone catchpit built into the brickwork and provided with wrought-iron outlet pipes 3 inches in diameter. The brickwork round the catchpits is carried up to formation level, and is finished off at the top with a 3-inch York stone flag. There are two abutment piers dividing the square arches into three sets of six each, and three large triangular piers; two of the latter carry the girders over the Hucknall Road, the third forming the junction between the square and skew arches near the south end. These piers have pockets arched over at the top, and are relieved at the sides by pilasters which are utilized at rail-level as refuges or manholes, the intermediate manholes being supported on stone corbels projecting from the face of the spandrils. The girders over the Hucknall Road have a span of 50 feet and are placed immediately under the rails. The piers and abutments are in some cases founded on the sandstone rock and in others on concrete upon the red marl, the average depth being about 12 feet.

A short distance to the south of the viaduct is the Bulwell Common station, of the ordinary country type, with the addition of a number of exchange sidings in connection with the branch lines, which have been constructed jointly with the Great Northern Company, giving access to the Leen Valley and Derbyshire lines of that Company. A little farther on is another junction, made for the purpose of enabling the Great Northern Company to run their trains from Stafford, Burton and Derby, over the line of the Great Central Company into the Nottingham Joint Central Station. At New Basford, the next station on the line similar to those already mentioned, carriage sidings have been laid down in connection with a large shed for storing and cleaning purposes, provision being also made for the manufacture of oil-gas for lighting the carriages.

Approaching Nottingham the line passes through the Sherwood Rise and Mansfield Road tunnels in the bunter sandstone, the lengths being 662 yards and 1,189 yards respectively. The first of these tunnels is straight throughout its whole length, and is on a gradient of 1 in 130. The second tunnel commences with a curve, is then straight for a short distance, and for the latter half of its length is on a reverse curve. The gradient throughout is 1 in 132. In each case four temporary shafts were sunk to formation level, from which the centre lines were set out and headings were driven. The dimensions adopted for the headings were approximately 12 feet square, large enough to allow the contractors' locomotives to pass through, the top of the heading being roughly worked in the form of an arch. The tunnels, being

driven through the solid rock, are only arched over with brickwork, no side walls being built except for short lengths at the ends (Figs. 11, Plate 2). Generally speaking, the brick arching is 1 foot 6 inches thick, built in lime mortar, but at certain places where the rock was found to be not quite so good the thickness was increased to 1 foot 10½ inches. The width between the rock sides is 27 feet, but the arch has a span of 29 feet, the springings being set back 1 foot from the face of the rock. The rise of the arch is 8 feet 6 inches, and the height from rail-level to crown is 20 feet. Manholes of the ordinary dimensions are formed in each side of the tunnels at distances of 66 feet apart, larger manholes or chambers 10 feet square being provided at distances of ¼ mile for the convenience of the platelayers. From the break-ups top headings were driven, the work being carried on from temporary platforms erected over the bottom heading, the top heading being afterwards widened out to the full width above springing level. The arching was turned in lengths varying between 12 feet 6 inches and 18 feet, the centering being supported on the rock left at the sides for this purpose, and the rock below springing was removed after the arch was turned. These tunnels are under the high ground on the north side of Nottingham, and for the greater part of their lengths they are at a considerable depth, the rock cutting at one end being over 70 feet deep, and at the other nearly 60 feet, the greatest depth from surface to rail-level being 120 feet. Between the two tunnels is Carrington Station, situated in a deep cutting about 7 chains in length, with inclined footways leading from the public road to the platforms. The rails at this point are 40 feet below the level of the roadway.

At the south end of the Mansfield Road tunnel is the Nottingham Central Station, the joint property of the Great Central and Great Northern Companies, which covers an area of 12¾ acres; the total length being about ⅝ mile, and the greatest width 390 feet (Figs. 3 and 4, Plate 1). It is situated in a deep cutting in sandstone rock, the depth varying between 24 feet and 58 feet, except at the southern end, where a considerable quantity of made ground had to be removed, the total amount of excavation being nearly 600,000 cubic yards. At the extreme northern end, where the cutting is deepest, the rock has been trimmed to a batter of ½ to 1, but at the southern end, where the soft soil had to be dealt with, heavy retaining walls have been built, the intermediate portion having walls varying in thickness and construction to meet the changes in the material to be retained. The whole of the retaining walls outside the covered portion of the station and the abutments of the

two public road bridges which cross the line are faced with Staffordshire brindled brick, the side walls carrying the main roofing being faced with glazed brickwork and vitrified terra-cotta to match the platform buildings.

The York Street Bridge, carrying a new road over the station, is 40 feet wide and 280 feet long, and consists of five steel plate-girder spans supported by steel columns resting on foundations built into the platforms, the western span being widened for the purpose of carrying the junction of two streets. The bridge crosses on the skew, and is built on a gradient of 1 in 132, the average height from the rails to the road surface being about 29 feet. Cross girders, supporting trough flooring on which the roadway is laid, are fixed between the main girders at intervals of 10 feet, and curved brackets riveted to the outer girders carry a light steel-plate parapet. The bridge carrying Parliament Street over the line is 80 feet wide between the parapets, the span varying between 126 feet on the north side and 76 feet on the south, owing to the divergence of the lines entering the station. The flooring is of corrugated steel plates resting on the top flanges of the main girders. The parapets, of light steel plating, are faced on the roadway side with a wall of red brick and stone. Nearly 1,400 tons of iron and steel were used in the construction of these two bridges.

The station has two large island platforms, each about 1,270 feet long and 68 feet wide, with bays for two roads at the end of each platform, giving in all twelve platforms with a total length of nearly 1¾ mile. The bays, each about 400 feet long, are for local traffic, the nine roads running through the central portion of the station consisting of the up and down fast main lines on the inner sides of the main platforms, connected to the middle siding by trailing points; the up and down slow mains on the outer sides of the platforms with passenger loop lines adjoining; and up and down goods lines for through traffic on the extreme outsides, clear of the passenger lines. Four signal-cabins are provided, two on the platforms at the middle, and one at each end of the station. The platform buildings, comprising dining-, refreshment- and waiting-rooms, with general offices above, are divided into four blocks, two on each platform. The blocks are each 135 feet long, 20 feet wide, and 40 feet high from platform level to the underside of the roof, provision having been made for an additional suite of offices on the second floor. At intervals of 15 feet riveted steel standards carrying the main roof principals are built into the side walls of the buildings, connected both longitudinally and trans-

versely by rolled steel joists. Between the ends of the blocks steel columns 30 feet apart, having ornamental cast-iron bases and corbels, and connected by arched lattice girders, form the support for the roofing, which is divided into three main spans. The roof principals, 15 feet apart, are connected by light lattice purlins carrying the glazing bars. The covering consists principally of Mellowes "Eclipse" glazing with $\frac{1}{4}$ inch rough rolled glass, a small portion only being of slates on boarding. Awning roofs carried on built steel columns extend for a distance of 222 feet both north and south of the main roof, and the total length of covered platform is 869 feet.

A public footbridge 15 feet wide, provided to meet the requirements of the Nottingham Corporation, crosses over the station and passes right through two of the platform buildings, necessitating special construction both in the main roof and the buildings for its accommodation. The main passenger footbridge, 20 feet in width, crosses the centre of the station, stepways 12 feet wide giving access to the platforms, and a footway 12 feet in width carried on cantilever girders alongside the parcels-offices provides a connection with the public footbridge. The main girders of these bridges are of lattice construction, supported on steel columns, the flooring consisting of rolled steel joists with arched steel plates between, resting on angle-bars riveted to the joists and covered with concrete, upon which the wood-block paving is laid. At the south end of the station the platforms are reached by means of a covered footbridge and steps leading from the Parliament Street bridge.

The main entrance is in Mansfield Road, where an extensive block of buildings has been erected with a frontage of 250 feet and a depth of 66 feet. The booking-hall, parcels-offices, cloak-room, etc., occupy the ground floor, general offices being provided on the floor above. The basement floor, which is about 4 feet above the rail-level, extends over the whole area of the buildings, involving the use of a large quantity of heavy steelwork. The greater part of the ground floor is carried on girders and columns, the construction of the floor resembling that of the footbridges already mentioned. Below the basement is the luggage subway at a depth of 40 feet below the level of the booking-hall floor, extending under the rails to the platforms in connection with the hydraulic lifts. The subway is 14 feet wide, with arched roof and side walls lined with white glazed bricks. Two large luggage-lifts are provided in the booking-hall, communicating with the basement floor and the subway, corresponding lifts being placed on the

platforms under the passenger footbridge. Smaller lifts in the parcels-offices and cloak-room connect with the basement floor. Subways 8 feet wide for the use of the refreshment department give access to the basement of the platform buildings from the main subway. Small subways have also been constructed round the platform blocks, giving accommodation for drainage, gas- and water-mains, electric cables, etc., so that they may be inspected or repaired at any time without interfering with the traffic on the platforms. Patent granolithic stone has been used for the coping and flagging to the platforms.

There are two parcels-offices, each 35 feet by 40 feet, with covered van-yard adjoining, and in the booking-hall, which is 104 feet by 46 feet, two booking-offices are provided, each 65 feet by 17 feet. The cloak-room, which is 50 feet by 40 feet, communicates with the booking-hall, and is to be used jointly by the two companies. A covered carriage-way extends for a distance of 100 feet along the front of the main buildings, and between this and the public street is the cab-yard. An inclined approach alongside the cab-yard provides access to the basement floor previously mentioned, and also to the horse, carriage and general loading docks on this side of the station. Similar docks have been constructed on the east side of the line, approached from Parliament Street by a roadway 15 feet wide, and on a gradient of 1 in 14, carried for some distance on brick arches, the openings thus provided being utilized as stores. A power-house supplies water at a pressure of 700 lbs. per square inch to the rams of the hydraulic luggage-lifts, the pumps being driven by gas-engines. Engine-turntables, 50 feet in diameter, have been placed at each end of the station, and the water-supply for locomotive purposes is obtained from a tank of 500,000 gallons capacity, erected on the high ground at the north end.

The ground upon which the station now stands was formerly covered for the greater part by dwelling houses—mostly in a very unsanitary condition—the demolition of which necessitated the building by the Company of 300 cottages on new sites. The old Nottingham Workhouse, St. Stephen's Church, and a number of factories, workshops, etc., which also occupied the ground, had to be acquired and demolished, the clearing away of these buildings being a work of considerable magnitude.

At the south end of the station the line enters the Victoria Street tunnel, 392 yards in length, passing under Thurland Street for a short distance, and then under shops, warehouses, offices, etc.

for the remaining length. The construction of this tunnel entailed costly and difficult work, the buildings overhead having to be carefully supported while the tunnelling operations were in progress. The portion of the tunnel under Thurland Street, for a length of 100 yards, was constructed as cut-and-cover, the cross sections adopted both for the covered way and for the tunnel being similar to those for the Sherwood Rise and Mansfield Road tunnels; and as the same class of sandstone rock is passed through, side-walls were unnecessary, except for the short lengths at the ends, as in the other tunnels. The excavation for the cut-and-cover length was taken out down to the level of the arch-springing, at which level the centering was fixed and the arch was turned. The brickwork for this portion is built in lime mortar, the thickness of the arch at the crown being 1 foot 10½ inches, and at the haunches 2 feet 3 inches. Tunnelling was commenced by a heading at the level of the arch-springing, which was afterwards enlarged to the full width and height required to take the brickwork, the foundations of the buildings cut through having to be supported on timbers until the arch was turned, when they were carefully underpinned with brickwork in cement. The whole of the brickwork in the tunnel portion is built in cement mortar, the arch in places being 3 feet thick. A short cutting with retaining walls follows, in which is situated another junction with the Great Northern Company's line, by which their trains from the south have access to the Joint Station.

At this point the ground dips abruptly and the line passes on to the Nottingham Viaduct (Fig. 7, Plate 2), which is about 1,000 yards in length, and crosses in its course through the city a number of streets, a canal, and the west end of the Nottingham passenger station of the Midland Company, which, by arrangement with that company, is spanned by a large steel girder bridge, the main lines and platforms being crossed by a single span of 171 feet, and a somewhat shorter span passing over the goods lines and sidings. The Arkwright Street Station is situated upon the viaduct, the platforms, waiting-rooms, &c., being supported on girders and columns, and approached by means of steps from the booking-office at the street-level.

The viaduct consists of fifty-three brick arches, with spans varying between 30 feet and 36 feet 6 inches, and one of 48 feet on the skew over the canal, and also twelve steel girder spans. The piers and abutments are in most cases founded upon good gravel, which was found after excavating through a great depth of silt and soft, dirty sand, the depth being in some cases as much

as 26 feet. Between 4 feet and 5 feet of concrete forms the base upon which the brickwork is built, and as a considerable quantity of water was met with, two or three courses of bricks were laid over the gravel before the concrete was put in, to provide a dry bottom and to prevent the extraction of the cement while the pumping was in progress, the water in the sump at the side of the foundations being always kept down below the bottom of the concrete. The foundations for the intermediate piers, carrying the girder spans over the Midland Railway, consist of cast-iron cylinders 12 feet in diameter, sunk under air-pressure to the solid rock, between 27 feet and 29 feet below the surface of the ground. The cylinders are filled with cement concrete, and above this is brindled brickwork in cement, upon which the stone beds for the steel columns are fixed. The columns are 5 feet by 4 feet and 17 feet in height, strongly braced together in pairs and held down by bolts built into the brickwork and cement concrete, roller-bearings on the tops of the columns allowing for expansion and contraction in the girder-work above. The girders for the north span over Station Street are 58 feet long, and were brought to the site complete; the girders over the centre and south spans, 172 feet 6 inches and 111 feet in length respectively, were built on timber staging, the cross girders and rail-bearers being first placed in position on the stage and the main girders erected over them. The flooring is continuous throughout the whole length of the bridge, the girders on the south abutment resting on fixed bearings, and those on the north abutment on rollers. The main girders are all of open-web construction, with suspended cross girders spaced at distances of 6 feet 4 inches apart, to suit the angle of skew to which the bridge had to be built. The Canal Street bridge crosses the junction of two streets, and has two main girders of unequal length, as the abutments are not parallel. The girders are of the open-web type, and have clear spans of 87 feet and 60 feet respectively. The cross girders are suspended and extend for a short distance outside the main girders, forming supports for light lattice brackets, introduced to steady the bridge, in place of overhead bracing which could not very well be used in this case. All the remaining girder bridges on the viaduct, with the exception of that near the south end of the Victoria Street tunnel, which is under the junction with the Great Northern, have three main girders, the largest of these bridges being that over Arkwright Street, which has a clear span on the skew of 67 feet. The bridge under the junction referred to crosses a footway and has a square span of 10 feet and a width of 65 feet between

parapets. The flooring is formed of girders 1 foot deep and 4 feet apart with arched steel plates carrying concrete between.

Upon leaving the Nottingham Viaduct the line crosses on embankment a space of about 33 acres, which has been laid out on the west side as a goods yard, with warehouse and offices, coal and other sidings, electric-lighting and hydraulic-power houses, etc., and on the east side as a locomotive yard, with running shed for sixteen engines, turntable, etc., and carriage-shed (Fig. 5, Plate 1).

The goods warehouse is 150 feet long (so arranged that it can be extended to 300 feet) and 128 feet wide, and contains three platforms on the ground floor with cart roads and sidings between, the two upper floors being adapted for the storage of grain, etc. Hydraulic cranes, hoists and capstans are provided for dealing with the traffic, with wagon-turntables at each end of the shed. The yard and buildings are lighted by electricity, which is also used for driving a goliath crane capable of lifting 25 tons. From the goods yard a short branch line connects with the Clifton Colliery.

For a distance of about ½ mile a goods loop has been laid down parallel to the main line, commencing at the south end of the Nottingham Viaduct and terminating on the south side of the River Trent. The viaduct over the river, which is in close proximity to the goods yard, is thus constructed to carry four lines of rails, the total length of the viaduct being 830 feet, 400 of which are made up of steelwork and the remainder of brick. The girder spans, four in number, form separate bridges, each bridge carrying two lines of rails. The brickwork portion of the viaduct is 74 feet 9 inches wide, and the arches are built for the full width. There are ten arches forming flood-openings and three girder spans of 103 feet on the skew over the river. The flooring is suspended, and the cross girders, rail-bearers and plating weigh 0·9 ton per foot run; including the main girders and overhead bracing the weight is 1·9 ton per foot run. The cross girders are spaced at intervals of 8 feet, and as the depth of construction was limited, owing to the requirements of the Trent Navigation Company and the desirability of keeping the rail-level as low as possible, the floor-plating is placed below the top flanges of the cross girders and is riveted to the web-plates. The flooring for three spans is continuous, the main girders resting on cast-iron sliding plates over the piers and on roller-bearings at the abutments.

Passing southwards the railway proceeds through an undulating country by the villages of Ruddington and East Leake, where stations of the country type have been provided, and through

some deep cuttings, a short tunnel and over a long embankment and viaduct to Loughborough, crossing the Midland main line at the latter place. Between Ruddington and East Leake a number of sidings have been laid down in connection with the Gotham Branch line, about 2 miles in length, which has been constructed for the purpose of giving access to several gypsum works. The short tunnel near East Leake, through the rhætic shale, is 99 yards long and required very careful timbering. It is inverted throughout, and the whole of the brickwork, faced with brindled brick, is built in lias lime mortar (Fig. 11, Plate 2).

The Loughborough Viaduct has a length of 198 yards, with an average height from ground-surface to rails of 30 feet. It is built entirely of brickwork; the arches are eleven in number, eight on the square and three on the skew. The viaduct crosses a diversion of the River Soar in the Loughborough meadows, and the average depth of foundations is 20 feet below ground-surface, the excavation being through sand and gravel down to the red marl.

The Midland main and goods lines at Loughborough are crossed by a girder bridge of four spans of 28 feet each on the square, the two side spans being provided for future widening. The spans are all of the three-girder type, and the piers and abutments are of brick.

The station at Loughborough has an island platform about 400 feet long, with space for future extension, and is 45 feet wide. An awning roof supported on cantilever girders rests on the walls of the buildings. The goods yard, which includes a warehouse and offices, has been laid out in a very similar manner to those for the country stations, but on a larger scale.

The next station upon the line, called Quorn and Woodhouse, is of the country-station class, laid out in accordance with the type plan. At stations where the public road adjoining passes under the line the entrance is formed by an archway in the abutments of the bridge, roofed steps between retaining walls leading up to the platforms. The overbridges at the stations are constructed so as to allow for the future widening of the line, and consist of two spans of 29 feet 6 inches each, with a centre pier so built as to form a cellar for coals or stores or, as in some cases where a fireplace is added, a porters' room. The span of 29 feet 6 inches was adopted so as to allow for a space of 9 feet 6 inches between the future additional lines of rails and the main lines. At the present time a small shed or office only is provided in the yard adjoining the site for a goods warehouse to be erected when required. Cattle-pens, horse-dock, and carriage-landing are con-

structed at the far end of the yard, the spare land taken for the future extension of the sidings being railed off in order to form an approach for the cattle to and from the public road. Station-masters' houses have been built at most of the stations, with a garden attached, a portion of the yard being utilized for this purpose. The widening of the main line is arranged for on both sides of the station, the land so provided being at present used for lie-by sidings where these are required.

Leaving Quorn Station and skirting the foot of the Charnwood Forest Hills, the line passes over the new reservoir of the Leicester Corporation upon two viaducts. A short distance farther south are the Swithland sidings, laid down in connection with a branch line to the Mountsorrel granite quarries. Sidings for general traffic have also been provided at this place. Passing Rothley, the next station on the line, Leicester, is approached by way of Belgrave, where a small passenger station has been constructed, and the line crosses the Thurcaston Road on an embankment 46 feet high. A large tunnel bridge 80 feet long carries the embankment over the roadway, the square span being 40 feet and the skew span 48 feet 10 inches. The arch has a rise of 18 feet 6 inches, and for the greater portion of its length is built with the courses parallel to the abutments, but towards the ends the courses are curved to meet those built from the skew faces at right angles to the heading spirals. This form of construction has been largely adopted in dealing with long arches with skew faces on this division.

Nearing the town the Abbey Lane coal sidings are reached, and about ½ mile farther the line enters upon the first portion of the Leicester Viaduct (Figs. 8 and 9, Plate 2). As at Nottingham, the line is carried principally upon brick arches, but there are a large number of girder bridges, which have been necessitated in passing over important streets and rivers, some of considerable span, such as Northgate Street, the River Soar, and Braunstone Gate. The first portion of this viaduct extends from the north end of the town to the Leicester passenger station, a distance of 781 yards, and the second portion from the station to the goods yard, a distance of 561 yards, giving a total length of 1,342 yards, of which 1,224 feet consists of girder spans. The viaduct passes over the River Soar at four different points. Near the north bridge, at 32 miles 58 chains from Annesley, the river is crossed by a girder bridge of two spans of 84 feet each. At West Bridge the river is crossed by a single span of 95 feet. The main girders, of the open-web type, are below the rails as before, but the flooring

and parapets are treated somewhat differently. The ballast-plates, instead of forming part of the parapets, are placed near to the ends of the sleepers, the side flooring being raised to rail-level and connected to the undersides of the parapets, which are carried on brackets curved upward to meet this level. At Braunstone Gate the line is carried over a road bridge and the river beneath by a single-span open-web girder bridge. At the end of the viaduct the river is crossed by a bridge having a clear span of 129 feet on the skew.

The bridge carrying the line over the canal and adjoining road is somewhat different in general appearance from those already described, as the main girders under the rails have plate webs and are fish-bellied in order to give the required headway over the road. Northgate Street is crossed on the skew, and owing to the widening out of the rails entering Leicester Station the main girders are not parallel. The main girders are of open-web construction, with suspended cross girders varying in length throughout the bridge. The bridge over Bath Lane at the south end of the station is considerably wider at one end than at the other. The main girders in this case have plate webs, with cross girders resting upon the lower flanges. There are in all seventeen steel girder spans in this viaduct, in the construction of which over 3,100 tons of iron and steel were used.

The brickwork portion of the viaduct is very similar to that at Nottingham, the arches having varying spans to suit the distances between streets, etc. The foundations were very deep, the depth being in some cases 20 feet and averaging about 15 feet. The average height from ground to rail-level is 23 feet.

The Leicester passenger station is situated between the two portions of the viaduct and is constructed partly on brick arches and girder bridges, and partly on embankment with retaining walls. All Saint's Road, which passes on the skew under the widest part of the station, is crossed by a girder bridge of 40 feet span, with abutments 194 feet in length. The rails are carried over Soar Lane on a girder bridge of similar span, the width, however, being reduced at this point to 115 feet, and over Welles Street on a girder bridge of 30 feet span with a width between parapets of 76 feet. The station has one large island platform 1,240 feet in length, with double bays at each end. The central portion of the platform is 80 feet wide, narrowing towards the ends. Six roads run through the station, viz., the up and down main lines, two passenger loop lines, and the up and down goods lines. Sidings are also provided on each side of the line, extending

nearly the whole length of the station, and connected by through roads and slips to the six lines before mentioned. The platform buildings are divided into three blocks, containing dining and refreshment rooms, waiting-rooms, etc., with subways under the platforms for drainage-, gas- and water-mains, etc. An awning roof the full width of the platform extends for a distance of 820 feet from end to end. The booking-hall and parcels-office, van-yard, etc., are at the street-level with a covered carriage-approach, facing a new street 50 feet in width formed by the Company. Access to the platforms is obtained by subways and steps, a special subway for passengers' luggage communicating with the hydraulic lift. Another new road has been formed on the opposite side of the station, from which a subway leads to the platforms and booking-hall, and also gives access to the store rooms, which have been provided in the basement. The rails are carried over the passenger- and luggage-subways on the east side upon corrugated steel flooring. The subways are 8 feet wide and the walls are faced with light buff glazed bricks. On the west side the subway is at a lower level, and here one of the ordinary 30-foot span arches carrying the railway has been used for the purpose, and is lined with glazed bricks. Under the south end of the station an interesting piece of Roman pavement is carefully preserved in the position in which it was discovered, a convenient chamber having been built for its accommodation, with access from the public street, the rails and platforms being carried over on girders. From the new street at the front of the station, a road-approach leads up to the docks for horse- and carriage-traffic, near which the engine-turntable and sidings are provided. The foundations are similar to those for the adjoining viaduct, the piers, abutments, platform and retaining walls, and also the foundations for the buildings, being carried down through soft clay, sand and gravel to the red marl, an average depth of 18 feet, or about 40 feet below rail-level. A bed of cement concrete between 3 feet and 4 feet in thickness forms the foundation, the brickwork above being built entirely in lime mortar, with the exception of the arch skew-backs where cement was used.

Upon leaving the second portion of the Leicester Viaduct, the goods yard is reached. The land required at this point covers an area of 66 acres, the northern portion being laid out as a goods yard, with warehouse, offices, hydraulic and electric-lighting power-house, &c., and also carriage-sidings and shed, with a building for the manufacture of oil-gas for lighting the carriages; and the southern portion as a locomotive-yard with running shed for

twenty engines, turntable, coal-stage, &c., and also a wagon-repairing shop, with accommodation for forty wagons. The old River Soar, which crosses the goods yard, has been diverted for some distance, and is spanned by several girder bridges which carry the various lines and sidings.

The Company were required to construct a new road 50 feet in width across the yard, and this is carried upon a viaduct 186 yards in length with inclined approaches at each end (Fig. 10, Plate 2).

Leaving the goods yard and passing under the Leicester and Burton Branch of the Midland Railway, the line runs in a southerly direction, and after passing over the Aylestone Viaduct it again crosses the River Soar, upon a girder bridge of 80 feet span, and thence proceeds in almost a direct line to Rugby, passing on its way Whetstone, Ashby Magna and Lutterworth, at which places stations of the country type have been provided. The latter portion of the line, for a distance of 16 miles, is through the open country, with earthworks of a heavy nature, fifty-nine bridges of various kinds and forty-four culverts with spans up to 8 feet, together with a short tunnel and a viaduct. A right-of-occupation road crosses the line upon the level about a mile south of Leicester, this being a special case, and the only level crossing on the 52 miles of line.

The arch bridges over the line have generally three spans, of 26 feet in the centre and 20 feet at the sides, but these dimensions are increased for deep cuttings. The parapets are built to a camber and the wing walls are curved slightly outward, and have a batter of 1 in 6. The rise of the arches is not less than quarter of the span, and the thickness at the crown not less than 1 foot 6 inches. The spandril-filling is of brick in the lower portion, and lime concrete above, with a paving of brick and asphalte as in the viaducts. Small artificial-stone catchpits are built over the piers, with a 3-inch wrought-iron pipe leading through the side arches. The width of the piers is generally 3 feet at the arch-springing and 3 feet 4½ inches below the plinth, the minimum height from the rails to the arch-springing being 10 feet. The brick arch bridges under the line vary in span between 12 feet and 45 feet, and where the embankments are high they have been constructed as tunnel-bridges.

The River Avon is spanned by a tunnel-bridge for a length of 73 feet 6 inches. The span of the arch is 45 feet, and the rise 18 feet, the thickness of the arch at the crown for the centre portion of its length is 2 feet 7½ inches, reduced to 2 feet 3 inches towards the ends, the haunches being 3 feet throughout. Brick

walls are built in the spandrils 3 feet thick and about 6 feet 9 inches apart, corresponding with the counterforts to the abutments, the spaces between being filled with concrete. The height of the embankment above the centre of the arch is 10 feet, and the total height from ground-surface to rails is 42 feet. The foundations have been taken down 10 feet below the ground-level and rest upon 6 feet of cement concrete.

The viaduct at Whetstone is 151 yards in length with thirteen arches of 30 feet span. The intermediate piers have a thickness of 4 feet 1½ inch, and the abutment-piers, of which there are two, are 12 feet wide, and have pockets arched over at the top. The height from the ground-surface to the rails is about 31 feet, and the foundations rest upon the marl at an average depth of 12 feet below the surface.

At Dunton Bassett there is a short tunnel 92 yards in length through boulder clay. The width of the tunnel at a point 5 feet above the rails is 27 feet, and the height from the rails to the soffit of the arch is 20 feet 6 inches. The brickwork was built in 12-foot lengths; the thickness of the arch and side walls is 2 feet 3 inches, and that of the invert 1 foot 6 inches (Figs. 11, Plate 2).

The land required for this country section of the line, including station-yards, road- and stream-diversions, etc., averages 15 acres per mile of railway.

At the time the Act was obtained and when the works were commenced, Mr. Alexander Ross, M. Inst. C.E., was the Chief Engineer of the Company, and it is due to him to state that the general designs and plans of the stations, goods yards and sorting sidings were prepared under his instructions and were issued from his office, as well as the type drawings of the bridges and the data for their calculations, the cross sections of the cuttings and embankments, and the particular type of permanent way adopted, which he had designed and introduced generally on the Company's lines a short time previous to the commencement of these works.

The Engineer of the works described was Mr. Edward Parry, M. Inst. C.E., to whom the Author acted as Chief Engineering Assistant. The contract between Annesley and East Leake was undertaken by Messrs. Logan and Hemingway, that between East Leake and Aylestone by Mr. Henry Lovatt; and the remaining portion by Messrs. Topham, Jones and Railton.

The Paper is accompanied by eleven tracings, from a selection of which Plates 1 and 2 have been prepared.

[APPENDIX.

APPENDIX.

Approximate Total Quantities—Northern Division.

Fencing (all kinds)	342,417 lineal yards.
Earthwork excavation	7,098,074 cubic yards.
„ foundations	522,841 „ „
Concrete	135,934 „ „
Brickwork	456,374 „ „
Ashlar	197,338 „ feet.
Earthenware pipes (all diameters)	221,309 lineal yards = 126 miles.
Culverts and sewers	24,485 „ „
Ballast	648,830 cubic yards.
Copings	58,595 lineal feet.
Steel and ironwork	21,000 tons.

Employed during the Construction.

Men	4,450
Locomotives	44
Steam navvies	18
Steam cranes	21
Portable engines	53
Horses	140
Trucks	239
Tip wagons	1,326

Total length of main line and branches, 57 miles 49 chains.

(*Paper No. 3209.*)

"The Great Central Railway Extension: Southern Division."

By Francis Douglas Fox, M.A., Assoc. M. Inst. C.E.

The Southern Division of this railway commences at a point 121 miles 44 chains from Manchester, and 51 miles 69 chains from the junction at Annesley, near Nottingham, with the original Manchester, Sheffield and Lincolnshire Railway, which, together with the new main-line extension to London (Marylebone Station), has been renamed the "Great Central Railway."

The railway runs in a southerly direction through the counties of Warwick, Northampton, Buckingham, and Oxford to a junction at Quainton Road with the Aylesbury and Buckingham branch of the Metropolitan Railway, where the Southern Division of the railway ends at a point 161½ miles from Manchester (Fig. 1, Plate 3). Junctions, both up and down, are provided at Woodford, with the East and West Junction Railway, giving access to Blisworth and Stratford-on-Avon. At Moreton-Pinckney, 138 miles 50 chains from Manchester, a double line branch, 8½ miles in length, runs from the main line in a south-westerly direction to a junction at Banbury with the Great Western Railway's main London and Birmingham line.

The main line between Rugby and Quainton Road passes through a rich grazing country, not thickly populated, which is generally of a smoothly undulating character, with ridges running east and west, consisting of lias and Oxford clays and beds of a softish white limestone. As the direction of the railway is almost due north and south, heavy earthworks were entailed in cutting through the ridges and embanking the valleys. Cuttings and embankments over 50 feet in depth and height respectively are of frequent occurrence, and in one case, at Catesby, where the ridge was of unusual height, a tunnel 3,000 yards in length was considered necessary.

The difficulty of crossing such country economically was increased by the fact that the maximum gradient allowed on this division was 1 in 176, or 30 feet in a mile, and the minimum curve was 60 chains radius, and that in one case only, the normal curve being of 1 mile radius. These severe restrictions were due to the Company's resolve to secure a first-class running line, as direct as possible, and with easy curves and flat gradients, so as to admit of high speeds. The highest point above the sea reached on this division is 503 feet (Fig. 2, Plate 3), at Charwelton Station, and between that station and Brackley the railway follows more or less the line of watershed, crossing the Cherwell river which flows west and joins the Thames at Oxford, and the Bedfordshire Ouse which flows east into the Wash.

Stations have been provided for passengers and goods as follows:—

LIST OF STATIONS.

Name of Station.	Class.	County.	Distance from Manchester.	Distance between Stations.
			M. C.	M. C.
1. Rugby . . .	Second	Warwickshire . .	122 60	1 16
2. Willoughby .	Country type	,, . .	127 35	4 55
3. Charwelton .	,, ,,	Northamptonshire .	134 40	7 05
4. Woodford . .	,, ,,	,, ,, .	136 70	2 30
5. Culworth . .	,, ,,	,, ,, .	139 70	3 00
6. Helmdon . .	,, ,,	,, ,, .	143 40	3 50
7. Brackley . .	Second	,, ,, .	146 60	3 20
8. Calvert . . .	,,	Oxfordshire. . .	151 40	4 60
9. Finmere . .	,,	Buckinghamshire .	157 20	5 60
		South end of Southern Division . . .	161 40	4 20
	Total . .			39 76

GENERAL DESCRIPTION.

Fencing and Gates.—The fencing throughout, except in a few places, where Local Board or private requirements had to be met, was of the ordinary post and five-rail Baltic creosoted timber type, standing 4 feet 6 inches high.

Earthwork.—In tipping the embankments no lift was allowed to exceed 20 feet, and as far as possible the tips were carried on together by end-tip wagons. On account, however, of the unusual magnitude of the earthworks and the limited time at disposal, the

[1] From commencement of the Southern Division.

Contractors were allowed in special cases to use side-tip wagons, working across from an end-tip bank at one side until the full width of the embankment was reached. The Author considers the question of end- *versus* side-tipping one of great interest, on which opinions seem to differ considerably. The heavy cuttings were excavated in lifts of about 16 feet deep by Ruston and Proctor steam-navvies, with gangs of men following close behind in the case of the side cuts, to trim the slopes, the steam-navvies working at night by the aid of the "Lucigen" light. The total quantity of earthwork excavated on the southern division amounts to some 6,200,000 cubic yards, 90 per cent. of this being stiff lias and Oxford clays. The success and rapidity of the excavation in cuttings was largely due to the system of drainage adopted.

The width of formation, Figs. 3, Plate 3, is 28 feet clear in cutting, and generally 31 feet clear on embankments, but the latter width was often increased to 33 feet, as there was a preponderance of cutting over embankment. The least clear width allowed between piers of bridges, etc., is 26 feet 3 inches. The minimum headway above rails is 14 feet 6 inches. The loading gauge is shown in Fig. 4, Plate 3.

Concrete.—Owing to the scarcity of good clean gravel, except on the sub-section from Charwelton to Woodford, it was decided to use clean ironstone slag and burnt ballast where stone could not be obtained. The Contractors installed a large sand- and gravel-washing machine at Woodford which did excellent work. Its capacity was about 30 cubic yards of washed gravel per day of 10 hours. The proportions of concrete used were, in ordinary foundations, 7 to 1 (5 of gravel or broken stone and 2 of sand to 1 of Portland cement); and 5 to 1 (3 of gravel or broken stone and 2 of sand to 1 of blue lias lime).

The concrete was brought up in layers not exceeding 2 feet in depth and well punned or trodden. It was entirely mixed by hand on boards covered with canvas to prevent waste. "Plums" or "burrs" were allowed to be used where the thickness of the concrete exceeded 3 feet. A layer of 1 foot of concrete was deposited, then one of plums of hard native limestone or Leicester granite placed on their flat beds, and not exceeding 12 inches in any direction, with 9-inch spacings between the blocks. Concrete mixed rather wet was then deposited around the plums, and carefully punned into place until the whole became an elastic mass. Plums were only allowed where the load to be borne was dead weight or applied normally. Mass concrete was allowed to be tipped into the foundations a barrow-

load at a time, where the depth did not exceed 6 feet. Upon the 12-inch layer of plums and concrete another layer of concrete 12 inches thick was deposited, and so on alternately. Only hard clinker-burnt clay ballast was admitted. This was found to make a durable and hard concrete with cement, lime having proved unsuitable for this purpose. Sand of an excellent quality, brought by train from Leighton Buzzard, was very largely used on contracts Nos. 5 and 6. The use of burnt clay ballast in concrete and mortar is, the Author thinks, a subject worth discussion.

Brickwork.—All brickwork was faced with Staffordshire brindle bricks in black mortar with an ordinary drawn weather-joint, which makes an excellent finish, and imparts a less sombre colour to the structure than the more expensive Staffordshire blue pressed bricks. Being of rougher grain, the brindle bricks bond better than the highly finished and smoother blue bricks, and are more easily handled and quartered. All copings to viaducts and bridges were built in Staffordshire double bull-nose blue brick, 14 inches and 18 inches wide. The brickwork was built in old English bond, with two "herring-bone" courses crossing each other at about every tenth course, in cement or blue lias lime, as ordered by the Engineers. All arch rings were built of unbonded work, except where the courses corresponded, and there headers were used as bonders. The bulk of the arch-work in viaducts and large arch bridges was built in cement. All brickwork in bridges and culverts below 12 inches above the level of the ground was built in cement. All brickwork in abutments and walls, etc., against which earthwork would lie, was backed up with 15 inches of broken stone dry lining, and the drainage was led by clay-puddle backing and weep-pipes to the front of the wall.

Stonework.—Stone, rock-faced, was used only in bedstones, pilaster caps, newell caps, and in a few cases in string courses, and was obtained from the Derbyshire gritstone quarries. Economy being of the first importance, very little fancy ashlar work was permitted, and for the most part brindle brickwork of substantial character was adopted throughout.

To insure safety in fast running, level crossings, whether of public roads, accommodation roads or footpaths, have almost entirely been avoided, bridges being provided, roads diverted, or the owners or public authorities compensated and the roads or paths closed. This should insure a great economy of working and the saving of the wages of watchmen, &c. Next in importance to a comparatively level and direct route, free from obstacles which

might limit the speed of trains, was the provision of a first-class road-bed, and to this end no pains were spared.

The slopes having been carefully trimmed and the camber of 3 inches high, 3 inches low, above and below formation having been formed at the centre and sides of the formation respectively, longitudinal side ditches were dug for the whole length of the cuttings, provided with glazed earthenware pipes, laid at twice their own depth over the flanges below the formation. They were puddle- or cement-jointed to their horizontal diameter, with clay-puddle from a pug mill carefully rammed to this level around the pipes, the space above the pipes being filled in with broken stone. Catchpits of brindle brickwork in cement, resting on Yorkshire flags with flag covers in two pieces, were built at every 5 chains under ordinary conditions, and more frequently if required. Compensating pipes were laid in concrete across the cutting at every 30 chains from catchpit to catchpit to provide against stoppage, and cross-cuts filled with broken stone were provided where the formation was wet. The country being almost entirely of the ridge and furrow system of cultivation, intersected by 3-inch and 4-inch unjointed agricultural pipes, and even by moss and rubble drains, these had to be very carefully tapped by one of the following methods:—

(1) In the case of embankments, a pipe was laid outside and parallel to the Company's fence on the high side, at a sufficient depth to tap these agricultural drains, which were carefully jointed to this longitudinal pipe catch drain, the same method of clay-puddle joints and dry stone filling as for the cutting-drains being adopted in order to catch any surface-water. To make things doubly sure the ordinary surface-ditch was provided just inside the fencing.

(2) In the case of shallow cuttings, if not more than 15 feet or so in depth, the agricultural drains were led down the slopes at the high side of the cutting into the longitudinal cutting-drain; or where there were no actual pipes, but only moss or rubble drains, trenches 12 inches by 15 inches were cut down to the main drain and filled with broken stone.

(3) In the case of deep cuttings it was thought advisable and cheaper to run a top heading drain alongside and outside the fence on the high side of the cutting, tapping the agricultural and other drains; and as it was considered of the greatest importance that no leakage or stoppage should take place in this pipe, thereby causing slips and wet places in the slopes, catchpits of the same type as those in the cutting were provided at distances of 5 chains apart, or less.

The advantage to the construction of getting rid of this water before more than the first lift of the cutting was excavated was incalculable, and it is to the elaborate drainage provided that the comparative freedom from slips in the blue lias clay is due. No great difficulty was experienced in obtaining permission from the farmers to place these drains outside the company's fences, and as far as possible from the top of the slopes.

Ballasting.—The specification was as follows: "The bottom ballast is to consist of hard rough stone pitching (approved by the engineers), each stone to be 9 inches deep, laid on edge, and hand-packed as closely as possible, and the top ballast of clean coarse gravel (thoroughly free from clay, loam, or sand) or of hard stone, broken sufficiently small to pass through a 2-inch ring, as shall be approved by the engineers, and it is to be laid upon the line and trimmed to the form and thickness shown on the drawing of the cross section. The quantity is to be 7,500 cubic yards per mile of double line." This was adhered to generally throughout the division. In soft clay cuttings, however, an initial blanket of burnt clay, clinker ballast, or coarse gravel, 1½ inch to 2 inches in depth, was provided, to prevent the large stone bottom ballast from squeezing into the clay. This was also found to dry up the formation very satisfactorily. A covering of about 2 inches of coarse gravel was provided over the bottom ballast, to fill up the interstices, and to prevent the top slag from becoming lost. On high clay embankments between 12 inches and 15 inches of burnt clay ballast was provided instead of the large stone bottom ballast, the top ballast remaining the same. For top ballast, 2-inch broken ironstone slag, from the neighbourhood of Hunsbury Hill, Northampton, was used extensively, and proved satisfactory. The slag was in all cases loaded at the works into trucks with ¾-inch pronged forks, or was passed over suitable revolving screens, to get rid of all dust and small stuff, and great care was taken to insure its freedom from honeycomb or porosity.

The permanent way used was as shown by the attached Table, which gives the weights per mile of single road.

Stations.—The only three stations of importance on this division are at Rugby, Woodford, and Brackley, the other six being of the ordinary country type. In order to economize in land, to enable the stations to be worked with the smallest possible staff, and to make future widening to four lines of way as easy and cheap as possible, the "island" platform system was adopted. In the case of a station on an embankment, as at Willoughby and Woodford stations, a staircase leads from the

centre of the bridge under the railway to the platform; in the case of a station in a cutting, the staircase leads from the centre of the bridge over the railway to the platform, as at Rugby, Culworth, and Brackley stations. This arrangement may have to be modified in some cases where there is no public road crossing the railway sufficiently close to the station. Allowance for four lines of way has been made in all station overbridges and in other bridges where conversion in the future would be otherwise difficult. A small hand-luggage lift is provided at Rugby and Brackley. Approach to the goods yards, etc., is in every case by inclined roads, with a maximum gradient of 1 in 30.

Types of Overbridges.—Brickwork was used in overbridges wherever possible, to save painting and repairs, etc., which entail an annual charge for maintenance where steelwork is used.

No. 1.—For headways, ranging between 14 feet 6 inches and 15

PERMANENT WAY (FIGS. 5, PLATE 3).—QUANTITY OF MATERIAL CONTAINED IN ONE MILE OF SINGLE ROAD, RAILS 80 LBS. PER YARD.

Description.	Quantity.	Weight. Tons.	Cwts.	Qrs.	Lbs.
Steel rails, 30 feet	352	135	2	3	12
Sleepers 9 feet × 10 inches × 5 inches (creosoted)	1,936	..			
Chairs, 51 lbs.	3,872	88	3	0	16
Spikes	7,744	3	4	2	4
Steel fishbolts, patent $1\frac{7}{8}$ lbs.	1,408	1	3	2	8
Steel fishplates, 14 lbs.	704	4	8	0	0
Trenails	7,744	..			
Keys	3,872	..			

feet 3 inches (between rail level and clearance of structure), plate girders, placed at right-angles to the railway, with brick-in-cement jack arches resting on their bottom flanges, were adopted. The girders, of 26 feet 3 inches span, were about 2 feet deep, spaced 4 feet $6\frac{1}{2}$ inches, centre to centre, the arching being 9 inches thick (all brindles), with cement concrete to fill up the haunches, and the whole upper surface of the concrete asphalted over with asphalt and cloth; the drainage was led to weep-pipes behind the abutments.

The parapets were of brick, standing on the outside girders.

No. 2.—*Special Station Bridge.*—The side spans were 29 feet 9 inches each, the extra 3 feet 6 inches being necessitated by a ramp which leads from the platform. This type was used for all station overbridges where the available headway was limited to 15 feet 3 inches. The side spans consisted of steel-plate girders

and jack arches, as in type No. 1. A gap in the parapet over the central pier allowed for a staircase which leads down to the booking-office and waiting-rooms on the island platform. The central pier is hollow, and provides a convenient porters' lamp-room, etc. Flat steel plates are placed between the outside girder and the second girder on each side, instead of the jack arches, to give space for pipes, gas-mains, electric-light cables, etc.

Types of Underbridges.—A feature in the design of the steelwork is that, in nearly every case, both up and down roads have a complete span and structure to themselves, so that in case of any damage to either half of the bridge, the other half is available to receive the diverted traffic; and one half can be repaired without interfering with the other half.

A. Where Headroom is not limited.—The plate girders are placed directly, or nearly so, under the rails, at 5 feet centres, and are well braced together. This arrangement leaves a free sleeper road. The floor consists of $\frac{3}{8}$-inch steel plates, covered and protected by a layer of asphalt $1\frac{1}{8}$ inch thick, over which the ballast is laid. The cloth asphalt renders the bridge quite watertight, and is laid with a camber sloping towards the abutments for drainage. There are steel-plate parapet-girders on each side, supporting a footway for the platelayers. The clear distance between them is 26 feet 3 inches (Figs. 10, Plate 4).

B.—This type was adopted for spans up to about 40 feet, where the headway was not sufficient to place the girders directly under the rails. There are two central girders and two outside girders, each line thus having a separate and complete span; a raised platform for platelayers is provided on each side, supported by flat plates resting on independent outside steel-plate parapet-girders. The span of this type is limited to the depth of the girder that can be used. The central girders must not be more than 6 inches above the rail-level, in order to clear the construction gauge. The cross girders are spaced at 7 feet centres, *i.e.*, 1 inch less than the distance between the centres of driving and trailing wheels of the heaviest locomotive in use. The rail-bearers are spaced at 5 feet centres, thus forming a continuous support directly under the rails. The floor is of flat plates, and the webs of the girders are protected from the ballast by rust-plates riveted to them (Figs. 12, Plate 4).

C.—This type is a modification of the preceding one, and is limited to spans of about 60 feet as a maximum, when the clear space between adjacent lines of way requires to be about 8 feet, to meet the Board of Trade regulations. The parapet-girder is

dispensed with, sufficient room being left between the rails and outside girders to afford shelter to the platelayers (Fig. 11, Plate 4).

D.—In special cases the former type was modified by using only one central girder, but owing to the difficulty of renewals this type was seldom used.

G.—For occupation roads, the bridges span 12 feet and are constructed of Hobson steel flooring and light steel-plate parapet-girders 5 feet 3 inches deep. Where headway is limited the flooring adopted is 12 inches deep, riveted to tees at 2 feet 6 inches centres, the flooring in the ordinary cases being 12 feet span by 26 feet 3 inches between parapets.

WEIGHT.

	Tons.
Floor	6
Joists	1
Parapets	1·5
Total	8·5

WORKS BETWEEN RUGBY AND QUAINTON ROAD.

The Southern Division of the Great Central Railway commences at a point 51 miles 69 chains from the junction of the Northern Division of the railway with the lines of the original Manchester, Sheffield and Lincolnshire Railway, near Annesley.

Oxford Canal Viaduct. (Figs. 7, Plate 4.)—The first work of importance, after leaving the Northern Division, is the Viaduct, which carries the railway over the Oxford Canal (which itself is on an embankment), and also over a portion of the Clifton Brook.

The viaduct comprises four spans of steel-plate girders, viz. :—

2 of 91 ft. each	=	182 ft. clear span.
1 of 90 ft. „	=	90 „ „ „
1 of 120 ft. „	=	120 „ „ „
Total . . .		392 „ „ „

Each span consists of four parallel girders, two carrying the up and two the down line, thus forming two distinct bridges. The timbers of the outer rails are carried on rail-girders between the cross girders. A $\frac{3}{8}$-inch steel decking, supported on the edges of the top flanges of the girders, runs from end to end. The southern abutment foundations were carried down about 6 feet, when some solid blue clay was met with. The next two piers, viz., those carrying the span over the canal, were sunk through the canal bank and rest on cylinders. The third pier is a brick-

in-cement structure 6 feet thick, carried up parallel in thickness. The northern abutment was carried well down into the dry boulder clay, as was also the brick pier.

In sinking the piers through the canal banks great care had to be taken, as there would have been a penalty incurred in the event of any obstruction being caused to the canal traffic, to the amount of £20 per hour and 20*s.* per thousand gallons for water wasted. Before commencing the sinking of these two piers, and to guard against the possibility of "drawing" the puddle lining of the canal in the operation, a special steel trough was used temporarily for the canal traffic. The centre-line of the railway crossing the canal obliquely, it was necessary to raise the temporary trough from its first position opposite the southern pier, which was first built, and to place it in its new position opposite the pier on the northern bank. The trough was 80 feet 6 inches over all, 8 feet clear inside width (which gave sufficient space for the passage of a barge), and 5 feet deep to the top of the steelwork. It was put together on the canal side and made watertight, and, by timbering up the ends and caulking, it was floated to its required position, and there sunk on to the bed of the canal by taking out the timber ends. The canal had been carefully sounded beforehand, and the trough was made to suit the depth of water. When the trough had been sunk into position a watertight puddle dam was constructed at each of its four corners to the canal side. If, therefore, any disturbance of the canal lining had taken place during the operation of sinking the cylinders, only a portion of that contained between the dams would have been affected, and the leakage of only a small quantity of water, viz., that between the canal side and the nearest side of the trough would have resulted.

When the first three sets of cylinders had been sunk, the trough was raised by re-inserting the timber ends in the grooves provided for them in construction, caulking, and pumping out the water, when the trough floated. Divers had to be employed in digging out the puddle from along the bottom before the attempt to lift was made. The same process was gone through in connection with the sinking of the second set of cylinders. When the cylinders had been all sunk and the girders erected, the trough was lifted out of the water and taken to pieces at the canal-side, the lifting being done from the top by a steam-crane. The trough was subsequently converted into a foot-bridge. No trouble of any kind was experienced with the trough, nor with the lining of the canal, and there were no signs of the

smallest leak from the canal during the sinking of the cylinders through the canal embankment.

There was nothing novel in the operation of sinking the cylinders. The correct position was carefully ascertained and set out, and a flat benching cut on the canal slope, on which was placed the lower ring or curb of the cylinder with a cutting edge on the bottom. There was no need to work under air-pressure when sinking, very little water being met with in four out of the six cylinders sunk. In the case of two cylinders, however, when sunk through the canal embankment and about 6 feet into the original ground surface, a thin bed of wet gravel was struck, which caused some trouble and delay, as steam-pumping had to be kept up continuously until the cutting edge had reached the clay below, when the inflow of water gradually ceased. In one of the cylinders the water from the same bed kept following down for many feet before it could be stopped. When the cylinders were sunk and filled they were loaded with cast-iron weights. The circular brickwork was carried up to springing and two arches turned. Trestles were then built between the piers and timbers laid in the usual manner to take a 3-inch decking, on which the girders were put together and riveted up. The steelwork was brought to Rugby by rail, was transferred into canal boats there, and was brought to the site by water and deposited on the canal bank, whence it was picked up by a steam-crane on to the erecting stage.

The total weight of steelwork in the canal viaduct is 675 tons in girders, bedplates, flooring, etc., and 96 tons in caissons. The weight is 1·90 ton per foot of clear span (including the weight of the caissons). The viaduct is approached by an embankment at the north end, the toe of which had to be protected by a concrete retaining wall, as the Clifton brook floods heavily in wet seasons.

Rugby Viaduct. (Figs. 8, Plate 4.)—The Rugby Viaduct crosses fourteen lines of way, consisting of the main lines, the Peterborough branch, and the sidings of the London and North Western Railway, and contains—

One	steel lattice girder		165 ft.	clear span.
Two	„	of 105 ft. =	210 „	„ „
One	„	plate girder	75 „	„ „
One	„	„ „	58 „	„ „

Then follow a series of 14 brick arches, viz.:—

1 of 14 ft. span .	=	14 ft. span.
13 of 26 ft. span each	=	338 „ „

These spans are taken across property where possibly an extension of sidings may be made. They will therefore enable the rails to be laid from east to west of the viaduct.

The arch-piers are 4 feet thick at the springing, tapering out wider towards the bottom, by means of plinths at different levels. The rise of arch is 8 feet 6 inches. The foundations of the piers throughout the viaduct are taken down into the blue clay, which varies in depth below ground, between 5 feet and upwards of 20 feet.

The lattice girders across the main lines of the London and North Western Railway were erected by means of a series of timber trestles, connected by whole timbers, on which were laid cross timbers supporting a 3-inch decking. A steam travelling-crane ran the whole length of the platform, and picked up from the ground below the various portions of steelwork required.

	Tons.
Total steelwork in the three lattice spans with flooring, bracing, etc.	634
Plate girders, etc.	187
	Ton.
Weight of steelwork per foot of clear span	1·61

The ends of the lattice girders are supported on fixed and rocker-bearings alternately, *i.e.*, the southernmost end of each span is fixed, and the other end rocks to and fro with the expansion and contraction of the metal. The bearings are carried on granite blocks, and are bolted through them and the brick pier into the concrete foundation. The piers are of brickwork in cement, faced with brindles.

After leaving the viaduct the railway runs over a high embankment, containing 300,000 cubic yards, and attaining a height of 49 feet, with a base of 31 feet and slopes of 3 to 1. The seat of the embankment was elaborately drained, by rubble and other drains, before the tipping commenced.

At the south end of the Rugby Viaduct the railway enters cutting No. 59, the largest on the railway, extending for a distance of 1¾ mile, and containing nearly 1,400,000 cubic yards of material, consisting of lias clays, silts, and pot-holes of dirty and wet gravel. A large quantity of water was tapped, and a deep heading drain, 9 inches in diameter, had to be laid to a depth varying between 10 feet 10 inches and 27 feet on both sides of the cutting, just inside the fences, before the steam navvies, which commenced working in running slurry, could make any headway. The water was pumped from these drains at all the low points by rotary steam-pumps working day and night. The flow from this drain has been considerable. A large reservoir

(90 feet 3 inches in diameter by 13 feet deep), capable of holding 500,000 gallons, has been provided near the station, in which the water is collected for the use of the locomotives. The formation of the cutting, when completed, was still found to be so wet, that, in the worst places, an extra spit, 12 inches to 15 inches in depth, was taken out and was filled up with ashes, burnt clay, ballast and broken stone. The formation was also extensively drained by cross cuts, filled with rubble, leading to main drains on each side, of 12 inches, 15 inches and 18 inches in diameter, with catchpits every five chains. The base of the cutting is 28 feet. Slopes under 20 feet deep 2 to 1; slopes over 20 feet deep 3 to 1. The cutting now is one of the most satisfactory on the railway.

The railway at the north end of this cutting runs through a new building area, and Chester Street, Rokeby Street, and Clifton Road had to be diverted, the former being passed under the railway, and the two latter over it. A special type of underbridge was used in the first-named case. The Rokeby Street and Clifton Road bridges were of No. 1 type.

Several sewer-culverts and siphons had to be provided, one 3 feet 6 inches diameter of brick, two of 18-inch and one of 9-inch cast-iron pipes. All pipes laid under any running lines or sidings were either of iron or, if of earthenware, were thickly encased in cement concrete to prevent crushing.

Rugby Station.—The Rugby station is approached from the Rugby—Hilmorton Road, for passengers, by a stairway from the bridge carrying the above roadway over the railway, for luggage by a hand-lift, and for goods by a roadway with a descending gradient of 1 in 30. There is also a separate 12-foot roadway, fenced in, leading from the public road to the cattle-docks and carriage-landing. The booking-hall is on the level of the public road. The platform is 500 feet long by 35 feet 6 inches on the surface, and 32 feet wide at rail-level. It tapers and reduces in width at the extreme ends; and of the total length 157 feet is roofed over. It is provided with the usual offices, and a parachute water-column stands at each end of the platform. There is also a 10-ton crane and a small warehouse. Beside the usual sidings, up and down "lay-by" sidings are provided, each 500 feet long, to allow for the shunting on one side of slow traffic.

Staverton Viaduct. (Figs. 9, Plate 4.)—From mile 131 southwards, to the neighbourhood of Finmere, the country is very undulating, necessitating heavy embankments and cuttings, with one tunnel. The first valley is spanned by the Staverton Viaduct, which is nearly similar in design to those of Catesby,

Brackley, Helmdon, and Willoughby. It is 357 feet long between the abutments, and has nine arches of 34 feet 3 inches span; and the maximum height from ground to rail-level is 60 feet. The foundations are in strong blue lias clay, the weight per square foot on which varied between 2 tons and 2¾ tons, including the rolling load. In plan the viaduct is straight, and it is built on a gradient of 1 in 176 rising south. It was decided to place inverts between the piers for its entire length. Partial inverts were therefore built, viz., three of 5 feet width in each of the three spans at the north and south ends, whilst the three centre spans had complete inverts, that is, of the same width as the viaduct. This viaduct runs practically north and south across the steep ravine intersected by a stream which feeds the River Leam on the east.

Catesby Viaduct and Embankment No. 2.—At 131 miles 47 chains the railway crosses the River Leam a second time by the Catesby Viaduct and Embankment No. 2. This viaduct, 476 feet long between abutments, consists of twelve arches of 34 feet 3 inches span at the springing, with a rise of 14 feet 6 inches. The piers are 5 feet 3 inches wide at the springing height, and in side elevation they taper 1 in 30, gradually widening towards their base. Transversely they taper 1 in 24. There is one stop pier 13 feet 1½ inch wide. The greatest height from ground to rails is 63 feet. The foundations are in strong blue lias clay, and range between 10 feet and 20 feet deep below ground. They were taken well into the pure blue clay, that which overlies it being a mixture of brown and blue clay in horizontal thin layers, and wet in places at varying depths from the surface. The weight is nearly 2½ tons per square foot on the blue clay with a rolling load. The drainage of the surface-water from the arch extrados is effected by sloping the spandrel concrete filling towards one side of the viaduct, and taking a drain-pipe through the spandrel wall to the hopper head of a down pipe at each pier. After the arches were turned, the outer spandrel walls were carried up as usual; and to divide up the concrete filling to the haunches two extra spandrel walls each 18 inches thick in cement brickwork were introduced, thus dividing the width into three separate pockets. In order to guard against the effects of the concrete swelling, after having been deposited in the pockets, and pushing the outer spandrel wall over the faces of the arches at the "collar" joint, some thin planking was introduced, or rather placed against one of the faces of each of the two inner spandrel walls; and after the concrete had partially set, these

planks were drawn, thus leaving two small spaces for the concrete to fill up if any swelling took place. After the concrete had set, the whole of the top surface of the viaduct from end to end was coated with asphalt in five layers, viz., three of asphalt and two of brattice cloth—one of each alternately. Inverts were built between all the piers in the first instance. Three of the inverts, viz., those on each side of the stream and that under the stream, were whole inverts; the others were partial inverts, viz., three of 5 feet width in each span.

In order to guard against the possibility of the bank at the south end slipping towards the stream at the bottom of the ravine and damaging the viaduct, extra precautions were taken by inserting concrete struts between the partial inverts at that end of the viaduct. The arches were turned in the usual way, the contractors using four sets of centering, and bringing forward the back centering as soon as advisable after that arch had been keyed in, proceeding in this manner from one end of the viaduct to the other. The viaduct is straight in plan, is built on a gradient of 1 in 176, rising towards the south, and crosses a steep ravine through which runs the River Leam from east to west.

Catesby Tunnel.—This tunnel is 3,000 yards long, 27 feet wide, and 25 feet 6 inches high, and of the section shown in Fig. 6, Plate 3. The whole of the brickwork is faced with Staffordshire brindles, and, where the position was wet, laid in cement. The formations passed through are the upper beds of the lower lias, and the lower beds of the middle lias. The tunnel was constructed according to the English system.

Roughly, for the first half mile from the northern end, the tunnel lies in what geologists call the Capricornus Zone of the lower lias; and here the ground was found to be very heavy, but on the extension of the workings into the Lower Margaritatus Zone of the middle lias, no difficulty was experienced, and the works were of a comparatively light description. As far as possible the tunnel was driven from nine shafts; but, unfortunately, owing to the wish of the landowner at the north end that the privacy of his residence, which was close to the workings, should be observed, no shafts were allowed within about 500 yards of this end of the tunnel; thus making it necessary to construct a length of about 264 yards in the worst part of the ground by means of a bottom heading and break-ups. A length of about 44 yards at the north end was carried out in cut-and-cover. This length might with advantage have been greater, as the ground was very shallow; the tunnel was, however, driven to meet the

cut-and-cover, although for the last two or three lengths there was very little cover; in the case of the last length, so little, indeed, that the two crown bars were actually laid in from the surface in a shallow trench, which was excavated to receive them, the remaining timbering being inserted in the usual way.

Great difficulty was experienced in keeping the heading open, and indeed it was only by constantly poling back and re-timbering that sufficient space was maintained to allow of the wagons passing. Bottom sills were used, and the side and head-trees ran about 10 inches to 12 inches in diameter (the heading being 12 feet × 10 feet) spaced as close as possible; but in spite of this there were constant breakages, and one part of the heading completely collapsed. This had the effect of disturbing the whole of the superincumbent material and of greatly increasing the pressure, which in its turn necessitated heavier work, both in the temporary timbering of the tunnel, and in the permanent lining. In a great portion of this part of the tunnel the lining was of seven rings in the arch and side walls, and six rings in the invert, laid in cement, faced with brindle bricks, and built in short lengths of 10 feet. The crown bars came down as much as 24 inches in some cases, and occasionally they were broken, although consisting of pitch-pine 14 inches square. The sills and sill-rakers were also broken. It may be interesting to note that the slope of disturbance of the superincumbent material was not steeper than 1¼ to 1. This was shown distinctly by wide cracks (as much as 2 inches wide) in a well-built and previously sound garden-wall built of brickwork.

As it was important, owing to the heavy nature of the ground, to brick this section in with as little delay as possible, the work was started from time to time (as the exigencies of the wagon traffic in the heading would permit) from five break-ups, and was diligently pushed on until all was securely lined. If this section could have been driven full-sized (as was done for the remainder of the tunnel) from shafts and without headings, the cost would have been reduced. The remaining length of the tunnel was nearly all of a light character, being lined with five-ring work in the arch and side walls, and four-ring work in the invert, faced with brindle bricks and built in lime mortar, with an occasional length in cement to stop an incipient movement.

In this part of the tunnel several beds of strong rock were encountered, of about 3 feet in thickness, which, when occurring above the work, tended to reduce the pressure, and when in the work itself, afforded a solid foundation for the timbering. The

clay also in this part of the tunnel was of an entirely different nature from that encountered at the north end, and with small face exposure stood for over a year without support. That at the north end commenced to move almost at once. The rock-beds referred to all contained water, but the quantity was trifling, amounting in the whole length of the tunnel to a fairly constant flow of about 80 gallons per minute. A large portion of this came from higher rock-beds, cut through by the shafts. At the north end of the tunnel there was practically no water, so that nearly the whole of the water came from the good ground. Here it had no appreciable effect in disintegrating the clay, or turning it into slurry, so that no wash-out behind the work was to be apprehended, and it was therefore considered quite safe to give it free drainage. This was done by means of chases built in the back of the brickwork at intervals, leading to pipes built through the side wall at rail-level, whence the water was discharged into the brick culvert in the 6-foot way. This water has been utilized to supply a garden and farmyard, about $4\frac{1}{3}$ gallons of the 80 gallons per minute being raised 168 feet by a hydraulic ram, and about 20 gallons per minute being allowed to flow to waste as a reserve to insure the injection head being kept constant. In one experiment, with an actual supply of 64·25 gallons per minute, 5·44 gallons per minute were delivered, thus giving an efficiency of about 71 per cent. for the whole installation. It may be noted that the delivery pipe was 3 inches in diameter, of cast-iron and 1,000 yards long. The head lost in friction was therefore inconsiderable (say under $2\frac{1}{2}$ feet). The large diameter employed was on account of anticipated fouling from lime deposits.

Ventilation is effected by five shafts, four of which are 10 feet in diameter, and the remaining one 15 feet in diameter. The diameter of the latter was increased, as (owing to its being on the boundary of the land on which permission could not be obtained for shafts) it was about $\frac{3}{4}$ mile from the north end of the tunnel, and had to be of much larger capacity to perform the extra duty. The gratings on the tops of the shafts are of expanded metal rolled into the shape of a hollow cone, which makes a light, if possibly inelegant, cap. Their great advantage is that stones roll off, and do not collect and load up the grating, and if the metal rusts away, then what is left can do very little damage by falling on passing trains, forming merely a shower of rust.

The tunnel is straight and on a rising gradient of 1 in 176 throughout towards the south, so that the setting out was simple. About 290,000 cubic yards of mining were executed, and

about 30 million bricks were used. The sinking of the first shaft was begun on 18th February, 1895, and the last length was keyed in on the 22nd May, 1897, giving an average rate of 110 yards per month, dating from the starting of the first shaft. The best progress was at the rate of 1½ foot per day at one face. The Author believes this to be almost a record in rapid tunnel building. The tunnel ends at about 133 miles 73 chains, where cutting No. 73A commences, containing over 410,000 cubic yards of earthwork. The slopes of this cutting were trimmed at 3 to 1, but in spite of this extreme flatness considerable slips occurred. The largest slip, about 66 yards long and 17 feet deep, occurred after the slopes had been trimmed, at a point where the cutting was 30 feet deep. On cutting a trench through, it was found that the upper portion was sliding bodily on a back or greasy bed. This slip was cured by burning it out.

Section No. 3 of the works, with the execution of which the Author was specially concerned, begins at 137 miles 34 chains. Owing to the East and West Junction Railway which crosses this cutting being already in a very wet cutting some 10 feet deep, which the Great Central Railway had again to undercut to give a headway of 15 feet from their rails to the underside of the girders, and the material being running sand and clay silt, the work was here extremely difficult. The whole of the brickwork in the wings and abutments had to be built in trenches sunk from the level of the East and West Junction Railway formation (before the cutting had been taken out) to a depth of some 25 feet, where, fortunately, a bed of blue clay of fair resistance was found. These short lengths of brickwork were all toothed, and lengths of old rails and hoop-iron were left projecting, in order to strengthen the bonds. The East and West Junction Railway being a single line, was, during the construction of the northern half of the bridge, slewed to the south sufficiently to give free access to the workings. The whole of the brickwork and concrete was built in cement, as the moment the steam-pumps ceased to work the foundations filled with mud and slurry. On the erection of the bridge and the completion of the cutting, four brick struts in cement were placed between the two abutments to prevent any squeezing in from the great pressure behind the walls. Mr. T. Thomson and Mr. A. H. Owles, the Contractor's Agent and Engineer respectively, deserve great credit for the way in which they met the difficulties of this piece of work. The traffic on the East and West Junction Railway was undisturbed during the whole of the operations.

At 137 miles 56 chains a double line gives access in a north-westerly direction to the East and West Junction Railway. This junction will, in the near future, be of great importance when the Stratford-on-Avon and Birmingham new railway is constructed, giving a short route from London to Birmingham. The only work of importance on this loop is a large three-arch bridge carrying the Woodford—Byfield public road. The foundations of this bridge gave considerable trouble in wet gravel and silt. In a triangle formed by the railways here, and severances, the Company have acquired over 14½ acres of land, admirably suited for workmen's cottages, workshops, etc., when the increasing importance of the junctions renders these necessary.

On leaving the East and West Junction Railway, the earthworks become very heavy, and at 138 miles 20 chains the Sulgrave embankment, one of the largest on the line, commences. It contains 432,000 cubic yards, its base is 33 feet and the slopes are 2½ and 3 to 1. Under this embankment there are two 12-feet occupation tunnel bridges, one of which, at a point where the height of embankment is 30 feet, is 30 yards long, and also a 10-foot culvert, 90 yards long, under 40 feet of embankment. An extensive peat-bog, varying in depth between 5 feet 6 inches and 8 feet, had to be taken out under a portion of this embankment and well drained.

The branch double line to Banbury leaves the main line at 138 miles 52 chains, just clearing the 10-foot culvert. A surface-slip took place in the widening of the embankment for this junction, in spite of the fact that the main-line embankment, previously tipped and consolidated, had been carefully benched to receive the extra width. This slip was cured by a concrete toe-wall and trenches filled with rubble and by burning the clay of the top portion of the slip to lighten it. At 139 miles 30 chains, heavy diversions of public roads were necessary, and an over-bridge of 25 feet between parapets, with plate girders and jack arches of 21 feet 3 inches span had to be constructed; and also another crossing, ½ mile further on, of the Canons Ashby to Culworth public road, with a bridge of 20 feet between parapets and 26 feet 3 inches span, plate girders and jack arches.

The next cutting, base 28 feet, slopes 2½ to 1, containing 534,000 cubic yards, inclusive of Culworth station yard, in stiff clay, is crossed by an occupation bridge, 12 feet between the parapets, of three segmental arches, each 55 feet 6 inches span; and at 139 miles 65 chains, where the cutting practically disappears on a gradient of 1 in 264. Culworth Station is reached, approached

from an overbridge, on a very extensive public road diversion, necessitated by the raising of the road 17 feet above the rails. This bridge is 25 feet between parapets, of plate girders and jack arches, with two 29-foot 9-inch spans; the extra 3-foot 6-inch span allowing for the spreading out of the rails for two ramps leading from the island platform. This road leads from Moreton Pinkney to Culworth.

It is unnecessary to refer in detail to the smaller cuttings and embankments, with the bridges of ordinary type built in connection with them.

The next important embankment, near Sulgrave, contains over 486,000 cubic yards, the base being 31 feet, slopes 3 to 1, and has two occupation tunnel bridges of the semi-circular 12-foot arch-type passing under it, one of them, built for Viscount Valentia, being of unusual length, under 43 feet of embankment. In spite of the flatness of the slopes, 3 to 1, several slips occurred, the blue clay being extremely sticky and greasy. The slips were the more remarkable as the surface of the ground was practically level and well drained. This embankment, covering a land area of 17 acres, is 340 feet wide, from fence to fence, at the deepest point. A culvert, 5 feet in diameter, takes the water of the valley through the embankment.

In this neighbourhood, near the Great Covert Wood, on 7 acres of land, the Contractors erected an elaborate brick-making plant, and, during the 36 months of construction, made some 12,000,000 stock-red bricks, of fair quality and practically free from lime. They also erected here navvies' barracks, with thirty beds.

A cutting, containing over 266,000 cubic yards with 2½ to 1 slopes, is spanned by a 25-foot public road bridge between Helmdon and Sulgrave, three 55-foot 6-inch skew arches, with 35 feet of cutting. The Company had no Parliamentary powers to divert this road, which was on a bad skew, but the Author, then acting as Resident Engineer, was able to negotiate with the local authorities for a diversion beneficial in the Company's interests, and reducing the cost of the bridge by one-third, which was approved by the Company and carried out. The rather parallel approaches were planted out from the railway by forest trees.

The Helmdon Valley, at 143 miles, with a stream liable to severe floods, and the Northampton and Banbury branch of the London and North Western Railway, are crossed by two embankments and the Helmdon Viaduct of nine arches, each of 34 feet 3 inches span and of the same general design as those at Catesby and Brackley.

Owing to the treacherous nature of the clay foundations, the distance between the piers was bricked in with five rings, each 4½ inches thick, of brindle-brickwork in cement. The invert under the arch over the London and North Western Railway was built in six portions, the rails being supported on longitudinal timbers. There was no interference with the traffic on the railway. A severe slip occurred at the south-west corner of one of the above-mentioned embankments, which was cured by a concrete toe-wall, and by lightening the embankment by burning. This toe-wall served both as a retaining wall for the slip and as a protection to the embankment from the floods.

A farmers' 12-foot bridge, 37 yards long, tunnels this embankment at a point where it is widened out to a width of 57 feet, for the purposes of Helmdon Station, approached by an over-bridge, carrying the Helmdon—Brackley Road on two spans of 29 feet 9 inches each, steel plate girders and jack arches. This road was also diverted, by agreement, thereby economising considerably in the cost of the bridge.

The Contractors had their branch offices, for this portion of their contract, and workshops, running-sheds, smithy, etc., in a field to the north of the viaduct, close to the foot-bridge crossing the stream. The offices, etc., were placed here for the convenience of a junction with the London and North Western Railway, but the position entailed a very steep overland route from the shops to the flood-level of the railway, viz., a gradient of 1 in 9 on a curve of 5 chains. It was found, however, that a contractor's locomotive, weighing 18 tons, could comfortably take two main-line wagons filled with slag, weighing in all 41 tons, up this gradient and stand and start on a gradient of 1 in 14. On a very dry day, a total weight of 75 tons (inclusive of the locomotive) has ascended this incline.

The next cutting, containing 445,000 cubic yards (inclusive of station-widening), with 2½ to 1 slopes, was composed of bluish clay, with a bed of disintegrated limestone rock, about 15 feet thick, at the bottom, which was partially utilized for pitching and bottom ballasting. Besides the above-mentioned station bridge, a 25-foot public-road bridge (Syresham to Greatworth) spans the cutting, three 55-foot 6-inch arches on the skew. The works from the south end of this cutting to 145 miles 30 chains are of a light description, with two 12-foot underbridges, with steel flooring placed longitudinally, and one 24-foot 7-inch skew span bridge, all carrying the railway over roads; also a roadway over the railway, on a segmental arch of 26 feet 3 inches span, with

approaches of 1 in 20 on each side, forming one of the many instances in which the Company preferred the expense of a bridge to an authorised but dangerous level crossing.

Cutting No. 97, containing 345,000 cubic yards, has one 12-foot farmers' road spanning it, carried over the railway in 37 feet of cutting, by one large 55-foot 6-inch segmental arch, with box wings. The small embankment, No. 98, is interesting only because here the first brickwork on the Southern Division was laid, in the 6-foot culvert under it, in November, 1894. A cutting, with 336,000 cubic yards (inclusive of the station-yard), leads to Brackley Station. This cutting was of a soft friable limestone, with slopes of 1½ to 1, with a bed of blue clay at about formation level, which caused it to be very wet, and necessitated two 9-inch diameter cutting drains.

Brackley Station, on a gradient of 1 in 264 falling south, is approached from a side bay, in the new Brackley Borough Corporation Road, the Corporation objecting to the public-road bridge at the north end of the station being utilized in the ordinary way, with steps leading from it, as they considered the station traffic might partially block the bridge for the important traffic from Towcester, through Brackley to Oxford. The line curves to the south-east, and crosses a deep valley of the Bedfordshire Ouse, partly on embankments of 470,000 cubic yards, and for 320 feet by the Brackley Viaduct, spanning a large area of flood land at a height of 62 feet. This viaduct is of the same general design as those at Willoughby, Staverton, Catesby, etc., but of greater length, consisting of twenty 34-foot 3-inch span arches, and two spans, each 35 feet, of steelwork, at the south end. The viaduct was inverted throughout, owing to the treacherous nature of the clay. There is nowhere a greater pressure than 2 tons per square foot on the foundations. One 12-foot farmers' bridge, 29 yards long, tunnels this embankment. The Contractor's head local office for contracts 5 and 6, and the Banbury Branch, was situated near the south end of this viaduct; and here were also workshops, large stables, and sleeping accommodation for 200 workmen.

Leaving embankment No. 100 B, the railway enters a limestone cutting containing two or three beds of extreme hardness, which were largely utilized for concrete in the foundations of Brackley Viaduct. Nearly the whole of this cutting, with the help of an occasional blast to loosen the rock ahead, was taken out by a Ruston and Proctor steam-navvy, which did excellent work. A single-arch, skew segmental bridge of 26 feet 3 inches square span, 33 feet

on the skew, with square box wings, spans this cutting, carrying the Buckingham to Brackley Road. Passing a small 12-foot underbridge, with steel flooring, and a 27-foot 4½-inch skew-span underbridge for the Turweston to Evenley Road, the railway crosses the main Bedfordshire Ouse Valley on a high embankment. In this valley the character of the clay was known to be very bad, from experience gained during the construction of the Banbury branch of the London and North Western Railway, which runs through it, and it was also found impossible to drain the seat of the embankment. However, a lift of about 15 feet high, for the full width of the base, was tipped of the dry material found in other neighbouring cuttings, and this no doubt, sinking down into the soft surface of the ground, helped to prevent any spewing out when the top weight came on. The Banbury branch of the London and North Western Railway at 148 miles 43 chains, is crossed by an overbridge, 26 feet square span, 51 feet on the skew; and 10 chains to the south, a small 12-foot underbridge is crossed, which is the last work on Section 3 of the works.

Section 4 of the works commences with a cutting of clay and gravel, and some soft limestone, spanned by two 12-foot bridges, one with an elliptical arch, where headway was limited, the other with a segmental arch, both being single 26-foot 3-inch spans. A trial bore-hole sunk in this cutting before the commencement of operations, happened to hit a pot-hole of good clean gravel and sand, but as a matter of fact scarcely any gravel or sand was found on this or the adjacent contract, the bulk of the latter coming from Leighton Buzzard.

A sunk road from Mixbury to Westbury, with the railway over it, on a bridge of 20 feet square span, 34 feet 9 inches on the skew, is at the north end of cutting 107. This cutting contains some 180,000 cubic yards, and is spanned by the following:—

The Shelswell and Westbury Road on a bridge with elliptical arch 26 feet 3 inches span; the Banbury to Buckingham Road, 35 feet between parapets with long approaches of 1 in 30 gradients, on a bridge of 26 feet 3 inches square span, and 33 feet 6 inches on the skew (type No. 1); an occupation road, 26 feet 3 inches elliptical arch with raised approaches; and a bridle road (Shelswell to Finmere), a timber structure with close-boarded parapets for the convenience of the Hunt.

At the south of the cutting the railway enters Finmere Station, which is approached by an underbridge, passing the Bicester to Buckingham Road under the railway, having a 30-foot square span, 36 feet on the skew (type B, adapted). The railway here passes

over an embankment of nearly 200,000 cubic yards, which is tunnelled by the above-mentioned bridge and by two 12-foot semicircular arch bridges, and enters cutting 109, spanned by:—

A bridge of three segmental arches, each of 26 feet 3 inches span, carrying the Tingewick and Stratton Audley Road. A bridge of one arch of 26 feet 3 inches span, semi-elliptical, carrying the Newton Purcell to Chetwode Road; and an occupation road, carried over the cutting by three semicircular arches, each of 26 feet 3 inches span, and again over an embankment. Then an embankment is reached, tunnelled by:—

A 12-foot occupation road; a public road from Goddington to Buckingham, under a bridge of 25 feet span with plate girders, etc.; and the River Ouse, which in this valley floods in every direction, and three separate bridges of three, one, and one openings respectively of 20-foot spans (each) had to be allowed (Figs. 13, Plate 4).

The works between the north end of the next cutting, and the junction at Quainton Road are of a comparatively light description. The contractor's branch offices for the contract No. 6 were situated near Finmere Station.

At 161 miles 41 chains the railway passes under the last bridge, carrying a public road from Waddesdon to Quainton, and at 161 miles 49 chains from Manchester the southern division terminates in a junction with the Aylesbury and Buckingham branch of the Metropolitan Railway.

The Chief Engineers were Sir Douglas and Mr. Francis Fox. The Author acted as Resident Engineer on Section 3. The Contractors for the works were Messrs. T. Oliver & Sons and Messrs. Walter Scott & Co. (see Appendix II).

The Paper is accompanied by seventy-nine drawings, from a selection of which Plates 3 and 4 have been prepared.

APPENDIXES.

APPENDIX I.

Approximate Total Quantities—Southern Division.

Fencing (all sorts), total	177,712 lineal yards.
Excavation in Founds—	
0–8 feet deep	75·54 per cent.
8–11 „ „	10·26 „ „
11–14 „ „	5·45 „ „
14–20 „ „	5·33 „ „
20–25 „ „	2·13 „ „
25–30 „ „	0·83 „ „
30–35 „ „	0·23 „ „
35–40 „ „	0·14 „ „
40–50 „ „	0·09 „ „
	100·00 „ „
Ashlar of all sorts	47,000 cubic feet.
Brickwork (all sorts)	182,000 „ yards.
Concrete	81,000 „ „
Earthenware pipes (all sorts)	144,000 lineal yards.
Special cutting drains, complete with catch-pits every 5 chains, etc.—	
6 inches diameter	36,600 lineal yards.
9 „ „	25,000 „ „
12 „ „	12,000 „ „
15 „ „	5,000 „ „
18 „ „	500 „ „
24 „ „	3,000 „ „
Total	82,100 „ „ = 46 miles.
Steelwork, total	3,100 tons.
Flooring, total	172 „
Bottom ballast	274,000 cubic yards.
Top ballast	198,000 „ „

Employed during the Construction.

Men	5,000
Horses	150
Locomotives	50
Steam-navvies	25
Wagons and trucks	1,700
Miles of temporary line (single), of 56-lbs. section Vignoles rail	98

APPENDIX II.

The Contracts.

For convenience of construction, and to insure rapid progress, the Southern Division was divided into four contracts, which were again subdivided into five sections for the Engineering staff, viz.: Contracts 4, 5 and 6, and the Banbury Branch, Contract 4 being subdivided into Sections 1 and 2. Contracts 5 and 6 subdivided into Sections 3 and 4, the Banbury Branch forming Section 5.

Contract Number.	Number of Section.	Ms.	Chains.	Length and Description.	Name of Contractors.
4	1	10	36	Rugby to the North end of the Catesby Tunnel	Messrs. Thomas Oliver and Sons of Horsham.
	2	5	33	From the North end of Catesby Tunnel to the junction with the East and West Junction Railway at Woodford.	
Total Length . . .		15	69	Of Main Line (Double)	
		0	35	Of Branch Line and Junction.	
Total length, Contract 4. .		16	24	Of Double Line.	
5	3	12	39	From the East and West Junction Railway to the crossing of the Bletchley and Banbury Branch of the London and North-Western Railway.	Messrs. Walter Scott and Co., of London and Newcastle-on-Tyne.
	4	12	61	From the Bletchley and Banbury Branch of the London and North-Western Railway to Quainton Railway Station on the Aylesbury and Buckingham Branch of the Metropolitan Railway.	
Total Length . . .		25	20		
		0	52	Junction Line to East and West Junction Ry.	
Total length, Contracts 5 & 6		25	72	Of Double Line.	
	5	8	40	The Banbury Branch.	Messrs. Walter Scott and Co.

Discussion.

Mr. HAWKSLEY, Chairman, was sure the members would accord a hearty vote of thanks to the two Authors for their most interesting Papers, which gave a clear and excellent description of the latest type of a main line of railway constructed in this country. He regretted to say that the absence of the President and of Mr. Francis Fox that evening was due to a severe domestic bereavement, in which, he felt confident, the members would sympathize with them. Mr. Hawksley.

Mr. F. DOUGLAS FOX wished to thank one or two gentlemen who had helped him in the preparation of his Paper, viz., Mr. Rowlandson, of the Great Central Railway, for the loan of a map; Mr. Casson, the Resident Engineer of the Rugby section, who had helped him considerably; and Mr. Hutchinson, of the Catesby Tunnel section, and Mr. Lawrence White, of the Southern section, who had given him valuable notes of their own experience on the works. Mr. Fox.

The Authors then exhibited lantern-slides illustrating the construction of the railway.

Sir DOUGLAS FOX, President, wished to express his regret that he had not been able to be present at the reading of the Papers, and that Mr. F. Douglas Fox was absent that evening owing to illness. If any reply was necessary to questions that might be put in the Discussion he would be happy, as far as he could, to answer for Mr. Fox. The subject of the two Papers—descriptive as they were of one of the latest main lines of railway constructed in this country—was of so comprehensive a nature that it would be almost impossible to discuss them as a whole; but he thought there were several rather practical points which might be brought out in the discussion, and he merely mentioned them by way of suggesting to the members matters for their consideration. One was the comparative merits of end tipping and side tipping. A good deal of question upon that matter had arisen in connection with the very heavy earthworks upon the line. He did not wish at the moment to express any opinion, but he suggested the point as one worthy of discussion. Then it would be observed that prominence was given in the Papers to the subject of the general drainage of the earthworks; and, considering the character of the Sir Douglas Fox.

Sir Douglas Fox. strata passed through in many parts of the line, it was believed that a great deal of the success achieved had followed from the introduction of adequate drainage, especially at the tops of the cuttings. Another interesting point was the curves which were permissible on a main line for fast traffic. The minimum radius for the curves on the Southern Division, with one exception, had been limited to a mile, and it was found that with that radius trains could travel at very high speeds without any detriment to their stability or the comfort of the passengers. One other subject he wished to mention was the question of island platforms for roadside stations as against side platforms. It would be observed that on the new railway the system of island platforms had been very extensively adopted, and that, he thought, was a question well worthy of discussion amongst engineers.

Mr. Middleton. Mr. J. T. MIDDLETON thought the Papers brought out many points which were frequently arising in railway construction. The works were of the usual type, but deserved perhaps more attention than ordinary works, owing to their magnitude. The amount of all classes of work carried out on the Great Central Railway, and the rate of progress, had probably exceeded anything previously attained. There were a few points in the construction, however, which presented somewhat novel methods. By reason of the line crossing the "roll of the Midlands," as it was called, at right angles, very heavy earthworks had been entailed, and consequently the question of slips had demanded the attention of the engineers. Mr. Bidder had referred in his Paper to the treatment of slips in embankments and cuttings by a system of drainage which he described as having the appearance of piers and arches in a viaduct, the vertical drains being connected at the top by a series of arched rubble drains. He could not see that the arching of the drains really was any great advantage, except of course that the top of the slip was thereby supported; and as far as his experience went, the provision of good-sized vertical drains going well down to the bottom of the slip, and extending right up to the top of the bank or cutting, as the case might be —or, at any rate, as far as the slip was observable—with diagonal drains striking out of them, was a more effective method of treating the slips. Greater efficiency was obtained in these vertical drains when they were made to taper on plan, having a greater width at the bottom than at the top and thus forming a sort of wedge-shaped counterfort, which tended to prevent the slipping of the earthwork. The question of end tipping *versus* side tipping, which had been referred to by Mr. F. Douglas Fox, applied, he presumed, only

to large embankments, such as had been dealt with upon this line. Mr. Middleton. He knew there was a prejudice against side tipping, and he thought it arose chiefly from the older practice, as it might be called, in the use of side wagons and side tips in forming embankments. In that case side tipping applied practically only to the filling up of the spaces formed between the end-tipping roads upon which the wagons were tipped. Those roads as a rule were 14 feet or 15 feet apart; and there was a triangular space left between each two roads. The use of side wagons hitherto had been—and, in ordinary practice on works of a smaller character than those under discussion, was—to fill up these spaces: also where a bank had been tipped rather narrower than it should have been, side tipping had to be used to make up the extra width. In both those cases there were no doubt objections, especially to thus widening a bank which had been tipped some time, in which case the extra width was put on to a more or less consolidated surface; and unless benching and other precautions were adopted, the application of side tipping in this way was likely to cause some difficulty with regard to slips. His experience, especially upon the southern section, where the banks were very heavy, with flat slopes, causing them to be exceedingly wide, made him decidedly of opinion that side tipping as now carried out on such works was far superior to the old end-tipping arrangement. In a large bank, say 50 feet or 60 feet high, tipped in two or three lifts, and having slopes of 2½ or 3 to 1, the bottom lift was a very wide one. By the method of end tipping in such a case, there would probably be in the lower lifts, say, a dozen end-tipped roads, 15 feet or more apart, with eleven triangular spaces between them. Those spaces, as a rule, were filled by the larger lumps of tipped earth which had fallen to the bottom at the end and at the sides: they were afterwards levelled up by side tips or by casting out, and thus the bank was composed of hard and more or less soft places, the hard places being those over which the wagons had been run and tipped in each end-tip road, and the softer places being those between the roads. That caused very unequal settlement of the bank; for the earth in the spaces between the tipping-roads was not consolidated by the passage of wagons over it, and water readily accumulated there in a wet season; and he ventured to say this was the cause of many extensive side slips. In railway embankments which, after having been tipped for some time, had settled through bad weather, large holes, in which a horse could be buried, would very often be found at places in the bank where the space between tipped roads had been filled. The advantages

Mr. Middleton. he claimed for side tipping were the following:—In starting the construction of an embankment on this plan, the work was commenced at the surface and at the outer edge of the slope. Side tipping went on, and the roads were gradually lifted and slewed until such a height was attained as had been fixed for the level of the first lift. Then side tipping proceeded right across that lift. He maintained that in this manner the impact of every train-load which passed over the embankment helped to consolidate it uniformly. There were no loose or open spaces such as might be found between end-tipped roads, the whole of the embankment receiving the benefit of the weight of the trains. The only danger he could see arising from it was, that when the outside tip was reached to form the full width there was rather a change of circumstances. The slope at which tipped material naturally stood might be said to be about 1 to 1. Supposing it was required to form eventually a slope of 2 to 1, that necessitated tipping it out a little farther, so as to have sufficient material to trim down; but if it was trimmed down without any great delay, there was no danger of slips, even on the outer loose end of the side-tipped bank. If it were allowed to remain there for months, it might cause trouble, but no more than would arise under the same circumstances in end tipping, because the side of an end tip could not possibly be tipped to such a flat slope as $2\frac{1}{2}$ to 1, which was a very common slope in embankments on the Great Central Railway, owing to the stuff that was in them. If end-tipped, it would have to be tipped with sufficient material to trim down to form a 2 to 1 slope; and if that were left, there was no doubt it would drag material away, and be the means of causing a slip. He had had an opportunity of judging from material taken out of the same cutting and tipped into two banks, one an end-tipped bank by the ordinary process, and the other a side-tipped bank such as he had described; and he had found that, while in the end-tipped bank large holes had been formed and the settlement on the bank had been certainly most unequal, in the side-tipped bank this obtained to a much less extent. He did not consider the suggestion made in Mr. Fox's Paper, that a narrow end-tipped bank should be tipped in advance for side-tipping purposes, to be of much advantage. From his own point of view, it certainly had great disadvantages —it involved additional cost, and the provision of two distinct sets of plant in the same cutting. He presumed the idea was that it contained the side-tipped material on one side, but he did not think this at all necessary. In advocating side tipping, he

was referring not to the old side tipping, but to the side tipping practised within recent years in the construction of heavy embankments: for a single line of the ordinary description he would say it was absolutely out of the question. A further consideration arose, which, he thought, ought to weigh with engineers generally, namely, that where there was a large quantity of earth coming out of a cutting which could not be worked from both ends, and the whole of the excavated material had to go into one large bank, far more rapid progress could be made by side tipping than by end tipping. There were several cases of this kind on the southern section in which between 60,000 cubic yards and 70,000 cubic yards per month was tipped into one bank from the same cutting. That was almost impossible with end tipping. He thought a point of this kind was a very important factor in the rate of progress of work in these days, when, no matter how long the promoters had been considering the scheme, when once it was put in hand they wanted it done in the shortest possible time; and it was undoubtedly important that every facility should be afforded to those who carried out the works. With regard to slips in cuttings, there was one source which, when excavating by steam-navvies, was very often probably not sufficiently considered. A steam-navvy was designed to excavate a certain cutting, the bottom of its cut being coincident with the slope at the level of the top, second, or third lift, as the case might be. The machine was driven through and the bulk of the cutting was excavated, but the wing or slope muck which the machine could not reach was left behind until a convenient season, and then it was lifted by hand. In excavating with a steam-navvy there was a slope of something like $\frac{3}{4}$ to 1, and the difference between that and the eventual 2 to 1 or $2\frac{1}{2}$ to 1 was the wing muck he referred to, which ought to be excavated and carried away not much behind the cut of the navvy. Instead of that, it was left practically hanging, and there was no doubt at all that in certain materials it dragged and was a fruitful source of slips in cuttings. On the southern section there were between 4,000,000 cubic yards and 5,000,000 cubic yards of earthwork, and the system of keeping the slopes roughly trimmed close up to the machine, together with the excellent system of heading-drains, had resulted in the fact that there had been very few slips in railway cuttings, and in no case had there been an extensive slip in a big cutting. Mr. Bidder had given some interesting information in his Paper with regard to the subsidence caused by coal-workings, and had referred to a bridge which settled 3 feet Mr. Middleton.

Mr. Middleton. without any signs of fracture, which spoke highly for the work. It would have been more interesting if he could have given some indication of the thickness of the coal-seams, and their depth below the surface, from which an idea might have been formed of the effect of the action which took place. He hoped Mr. Bidder would further enlighten the members as to the methods adopted for the support of the buildings tunnelled under at Nottingham, and also state the depth of the tunnel below the buildings. That was an important question, especially in London, where tunnelling was proceeding in close proximity to large, important and valuable buildings; and he was sure that any information Mr. Bidder could give on such matters would be of great value to the Institution. Both the engineers and the contractors were to be congratulated upon having attained a record of progress in the Catesby Tunnel. It would certainly be interesting if Mr. Fox could say something more about the number of faces worked, the methods of ventilation adopted, and other points in connection with the progress of that tunnel. One point which seemed to him rather a novelty in the treatment of foundations of bridges and viaducts was referred to by Mr. Bidder, namely, the laying of courses of bricks on the foundation before putting in the concrete. He had not himself seen any method of that kind adopted, and he would be very glad to hear that it was useful and effective. Mr. Fox had invited discussion on one other point, namely, the use of burnt ballast in concrete. His own opinion was that good, well-burnt clinker-ballast was an excellent material, mixed, of course, with sand, for making concrete, especially in such a district as that in which the works under discussion were situated, where no other material could be obtained; and also for mixing mortar, where clinker-ashes and sand were not to be had. Burnt ballast was certainly in no way deleterious to work. It had been used largely on the southern section of the line, where there was no gravel and very little stone, and that only at one place; and he knew of no instance of failure. The method adopted in crossing over the Oxford Canal near Rugby, where the navigation had been conducted in a steel trough, appeared to him to be unique, and he knew from his own observation that it had been entirely successful.

Sir Leader Williams. Sir E. Leader Williams said that the question of end and side tipping was one about which engineers differed, and he did not think an absolute rule could be laid down to be followed in all cases. The engineering profession had to adapt itself to all circumstances. Where there was sound ground to work upon

Sir Leader Williams.

and good homogeneous material suitable for a high bank, he did not think the method of tipping made any difference whatever. His experience on the Ship Canal at Manchester, where between 45,000,000 cubic yards and 50,000,000 cubic yards of excavation had had to be made, a large part of which was run to high embankments, aggregating about 8 miles in length, to enable railway viaducts to be carried over the Ship Canal, was certainly very favourable to side tipping. The contractor, Mr. Thomas Walker, had gone to large expense in putting heavy plant on the works, and he had included a large number of side-tipping wagons. In his early days, when he had been Assistant Engineer under Sir William Cubitt on heavy embankments on the Great Northern Railway near Gainsborough, nearly 50 years ago, his usual custom had been to run end-tipped banks well ahead and follow up in the centre, a plan which was rather captivating. With a good piece on either side the centre could be filled up, and it could be easily understood that with good material it was a nice way to make a bank. Those embankments had been on difficult boggy ground just before the Trent was reached, and there had been considerable difficulty in carrying any drainage underneath. Culverts very soon had to be given up, and the difficulty had been met by the use of large cast-iron pipes with spigot-and-faucet joints and india-rubber rings something like 3 inches in diameter, which had made the whole thing very elastic. When the bank had been tipped over the pipes, they had raised themselves up vertically on each side of the bank, and horizontal ends had been obtained, which had rendered the method of constructing the culvert-ends a rather puzzling problem. The bank had given no trouble afterwards, although it had been tipped in that way. If he had to deal with boggy ground of that sort again he was not at all sure he would not prefer end tips; but when he mentioned that in the 8 miles of embankment formed from the excavation of the Ship Canal, and done almost entirely by side tipping, there had been no slips or trouble whatever, he thought very little could be said against the system. One of its advantages was that it was possible to tip with much greater rapidity than by end tipping. A train of twenty or thirty wagons was used, which were all brought into line; the tippers then used the levers, and the whole was shot out at once. At the same time he was bound to say that the material used in the Ship Canal embankments had been very good, and there had been no boggy ground to put the banks on. He might mention a very interesting feature of the Great Central Railway

Sir Leader Williams. works which perhaps might be useful to engineers whose practice had been identified with canals. The railway crossed the Oxford Canal at a considerable elevation, and the canal was on an embankment; the piers had had to go through the embankment, and other things had not been very favourable. The work had been successfully carried out, and he thought the way in which the difficulty had been overcome by means of an iron trough was ingenious. He had been struck with the fact that the engineers had wasted nothing, Sir Douglas Fox having used up the old trough afterwards for a footbridge over the line.

Mr. Fox. Mr. F. G. B. Fox said one of the members had spoken about side tipping, and he had had experience in Madras and Northern India of cuttings in which the strata varied considerably. If the earth obtained from the cuttings was of one quality throughout, side tipping was doubtless a very good thing, but in cuttings 80 feet or 90 feet deep the quality of the earth often varied. Many years ago a slip had occurred on the Madras Railway, owing to a large accumulation of water between the different layers of earth in an embankment which had been made by throwing up a bank in the centre and tipping on its sides. The whole side of the bank had been washed away, and the line had subsided and caused an accident. That was an illustration of one of the disadvantages of side tipping. If tipping were started from the bottom, and spread all over, that would be avoided. With regard to brick ballast, in India there were many thousands of square miles where no stone of any kind whatever was to be obtained; and engineers there had to use broken-brick ballast for concrete, as well as for road-metal and other things, and they never found any difficulty with it. He thought clinker ballast was quite as good as any stone for concrete. It might not be quite so heavy, but he had broken the concrete 9 months old, and the ballast had showed as if it had been cut through with a knife, the mortar having adhered to it so firmly. In the mortar itself the brick or burnt clay combined chemically with the lime and formed a hydraulic mortar. It was well known that pozzuolana had been used in Europe for many years, and he did not see that there was any objection to it.

Mr. McDonald. Mr. J. A. McDonald remarked that the question of using burnt ballast for concrete was a very old one, and one often arising. There was no doubt that concrete made from burnt ballast was much lighter than that made from gravel or broken stone; but, on the other hand, if the ballast was well burnt and used with lime, not cement, the result in concrete was an extremely good

Mr. McDonald. material. He saw in the room Mr. Richard Johnson, who, he thought, had built more walls of concrete made of lime and burnt ballast than anybody else, and he felt that the Institution would be glad to hear Mr. Johnson's views on the subject. About a couple of years ago, when he had been widening the portion of the Midland Railway between Kentish Town and St. Pancras, he had had occasion to pull out some very large masses of concrete formed of burnt ballast and lime, which had been put in at the back of the walls built by Mr. Barlow 25 or 26 years before. The walls had moved in consequence of a very extensive slip, running back a long way from the railway, and moving on a slippery bed which made a very slight angle with the horizontal. On the walls showing signs of movement, the large masses of concrete had been put in. He believed they had been all formed of about 5 or 6 to 1 lime concrete made (in most cases) of the actual material excavated to form the holes into which the concrete had been put. When the walls had come to be pulled out great difficulty had been experienced. The concrete had been comparatively light, but so tough that the contractor had had the greatest trouble in getting it out, and he thought he was safe in saying that by the time it had been loaded into the wagons there was very seldom a piece measuring a cubic foot. He thought that showed that when lime was used—he did not like burnt ballast with cement—the resulting concrete was a very useful material, and there were many ways in which it could be adopted successfully.

Mr. Johnson. Mr. Richard Johnson had used a great deal of burnt ballast in concrete and also in building walls, principally in the neighbourhood of London, and he had no hesitation in saying that burnt ballast, say 25 per cent. of burnt ballast and 75 per cent. of good gravel with cement, made very good concrete. Mr. McDonald had spoken rather slightingly of cement, but his experience was that cement made a very good concrete indeed. Mr. Alexander Ross, was just now about to pull down some walls which he (Mr. Johnson) had built a few years ago, and he wished Mr. Ross every success in getting them to pieces. He was sure he would find that there was a fair proportion of burnt ballast in those walls, and he hoped the members would not be afraid of cement in concrete. No doubt cement did play tricks in brickwork sometimes. As was well known, it required a good deal of humouring and keeping before it was used. With regard to Nottingham Station, his friend Mr. Parry had prepared innumerable plans for that station. Originally it had been designed as a one-company station, and

Mr. Johnson. there was to have been one island platform. It had been his misfortune to be in opposition, and he had said there must be two. The Great Northern Company were joint owners, and he had said that to construct a station with one platform for two rival companies would never do. Eventually the point had been carried and two platforms had been built. There was at Nottingham a weak point on the Great Central Railway. From the section it would be seen that Nottingham Station was approached from the north by very long tunnels, having only two lines of way. He had often said to Mr. Parry that he ought to construct four lines of way at that point; for the experience of the last 40 years had been that the great railways of this country had been throttled by the insufficient tunnels which had been constructed in the early days. Of course, Mr. Parry had said he had no money for more, and that he had been obliged to be satisfied with two-line tunnels. Nevertheless, that was the weak point, in his opinion, in the Great Central Railway as a trunk line. At a place like Leicester, where the ground was perfectly open, it was possible to double the railway easily. During the last 30 years he had had to carry out many additional tunnels on the Great Northern Railway. It had been found that without those tunnels trains were delayed, and the four lines of way were of comparatively little use; and eventually additional tunnels had been, and would have to be, constructed so as to give a free course to the traffic. In the case of the Great Northern Railway the members were probably aware that in the Session of 1897 power had been obtained to construct an entirely new railway from Stevenage to Enfield, so that on the part of the Great Northern Railway south of Potter's Bar where the long tunnels were, additional tunnels would not be constructed, but an entirely new line from Stevenage to Enfield, joining the existing railway at Enfield, would give freedom to the traffic.

Mr. Sadler. Mr. H. W. Sadler remarked that he was in the unhappy position of having to pull down the walls in the neighbourhood of Finsbury Park to which Mr. Johnson had referred, and was therefore able to speak as to the quality of cement walls made with burnt ballast. Concrete made with burnt ballast was certainly very good, but it did not take so much pulling down as that made with gravel, and he thought this was owing to the softness of the ballast. It was found that almost the only place where the walls could be broken up was at the junction of the layers. When built they had been carried up in 12-inch or 18-inch layers, and by driving wedges between the layers the top

broke up and the walls were thus removed. That seemed to show Mr. Sadler. that concrete, in walls at any rate, should not be built in layers, and an endeavour was being made in the walls now in course of construction at the back of those to which Mr. Johnson had referred, to leave the layers in the rough when leaving off at night, so as to form a key for the work on the following day. There was only one other point he wished to mention, and that had reference to the sorting-sidings at Annesley. Looking at the diagram, Fig. 2, Plate 1, it would be seen that, in the sorting-sidings on the up side, the wagons came into the reception-sidings at the north end, ran down into "departure" or sorting sidings (commonly called the "grid"), and thence passed out by the south end. He ventured to think that was the right system. On the down side, however, it would be seen the wagons had to go northward by what was called the arrival road into the reception-sidings; then they had to be run southward down the reception-sidings into the dead-ended "departure" or sorting-sidings, and finally they had to travel back again to go away to the north. Every wagon had to pass the point just below the repairing shops three times, and the shunting had all to be done over the same neck. As Mr. Johnson would remember, when the sidings had been laid out at Colwick—and the sorting-yard there was one of the largest in the kingdom, if not the largest—an exactly similar arrangement had been made for the wagons going down the line with "empties," and it had been found that so many delays occurred at the "bottle neck" that the Great Northern Company had had some time ago to spend a large sum of money in making a fresh set of sidings on the system of those shown on the up side. He had had the pleasure of carrying out the alteration under Mr. Johnson, and it had been found to work very well. The proper system for gravitation-sidings was for the wagons to be run in at the top or arrival end of the gradient, and down to the bottom or departure end, towards their destination; and "dead-ended" sorting-sidings were always a source of trouble. He knew Mr. Parry's difficulty at Annesley had been the gradient. As would be seen from the section, it ran down from north to south 1 in 132, and no doubt considerable expense would have had to be incurred to make an incline up so that the sidings would have run from south to north; but he ventured to say the Great Central Company would regret some day that they had not gone to that expense.

Mr. Johnson was very glad Mr. Sadler had made that remark. Mr. Johnson. He thought the weak point of those sidings was at that place.

Mr. Robertson. Mr. F. E. Robertson remarked, with reference to what Mr. Sadler had said about partings in the wall, that at the end of the day's work in building a concrete wall it was always expedient not only to rack the work back in steps, but also to leave in some good big stones to form a key to the next day's work, and so avoid the defects found in pulling down walls where a plain surface had been left. With regard to the use of burnt clay in general, in some parts of India that was the only material available for ballast and for concrete; and he thought it was as good as most stone if, instead of burning the clay in lumps, the precaution was taken to first mould it into tiles about 12 inches square and $1\frac{1}{2}$ inch thick. They could be cheaply slop-moulded on the ground slightly smoothed. The tiles were easily vitrified, easily broken, and very good both for ballast and for concrete.

Mr. Galbraith. Mr. W. R. Galbraith thought it was a pity that, having regard to the great importance of the line, the Great Central Company had not seen their way to construct the last two miles of the line, between the neighbourhood of South Hampstead and their terminal station, with four lines of rails at once. From a little to the north-west of Swiss Cottage there were only two lines, and having regard to the somewhat unfortunate state of matters between the Great Central and Metropolitan Companies, it seemed to him that the Great Central had to depend mainly on their own line for their traffic. If the traffic increased, as everyone expected it would, and especially if the passenger traffic increased with the goods and minerals, it would be soon found that the two lines of rails were quite inadequate, and the company would have to double them at a considerable cost. The big companies now running into London had had occasion not only to double, but sometimes even to treble their lines; and he thought his old master, Mr. Locke, had been wise when he had made the London and South Western line from Vauxhall into Waterloo with four lines of rails something like 50 years ago. The South Western Company, for their passenger traffic alone, had been now obliged to make that into six lines, and even those were hardly sufficient for the traffic. Therefore he thought the Great Central Company would have been wise if they had spent more money in making at once four lines of rails into their goods and passenger stations. With regard to curves, his impression was that the minimum radius adopted might very well have been diminished. He thought a radius of 60 chains, or $\frac{3}{4}$ mile, would take traffic at any speed which could be run. On the London and North Western line to Scotland, and on the Caledonian line, very high speeds were

attained down the inclines, the running over 60-chain curves being effected with perfect facility, and without any disagreeable swing. On some of the lines of the North British Company, from the Forth Bridge northwards, there were curves of considerably shorter radius; in particular on the Glenfarg line leading to Perth, it had been necessary, for the sake of economy, to put in a long 30-chain curve. Over this the trains frequently ran at 60 miles per hour, apparently with very little discomfort. He thought, therefore, he would not have hesitated to put a 60-chain curve on the main line. Mr. Galbraith.

The PRESIDENT said it should be remembered there were reverse curves. The President.

Mr. GALBRAITH thought if there was a proper length of straight between the two curves no great inconvenience would be found. He believed his friend Mr. Hawkshaw contemplated a railway between Liverpool and Manchester, where the speed was to be something far beyond present experience in this country—he thought at least 100 miles an hour. There the curves were hardly so flat as 60 chains radius. If anything was to be gained by the introduction of 60-chain curves he would not hesitate at all. There was no doubt that for the easiest and steadiest running a curve with a radius of about 2 miles was superior to anything—far better even than a straight line; because there was less oscillation, practically no extra resistance, and a slight bearing on the outer rail, which seemed to steady the train when it ran at high speed. Nothing could be more splendid than the goods station at Marylebone Road, with all its appliances. Everything seemed to have been laid out without regard to cost, and in the most satisfactory way. He only wished the passenger station were filled with traffic, but no doubt that would come in time. With regard to the permanent way, he gathered that where stone ballast was available, large stone about 9 inches in thickness was laid on the formation. He did not quite understand what amount of small ballast there was above that. If the ordinary thickness of 12 inches of ballast below the sleepers was the rule in that case, it seemed to him there was hardly enough small ballast above the heavier ballast to pack, especially as contractors sometimes read "a 2-inch ring" rather freely. No doubt some heavier stone in the bottom was a good thing for drainage, and he thought there ought to be at least 5 inches or 6 inches of smaller material or gravel above, to sufficiently pack the permanent way. Mr. Galbraith.

Mr. J. C. INGLIS thought the fact of the Papers coming at that Mr. Inglis.

Mr. Inglis. moment was a very fortunate circumstance for the Institution's Proceedings. There was no doubt that as time went on they would become more valuable as being a complete record of the construction of a first-class line, 90 miles in length, in this country. He hoped, therefore, that the Authors would give more detailed particulars of the permanent way, especially of the rails, and of the permanent-way fastenings and fittings, which were not the least important items in the construction of an express line in the year 1900; and he would suggest that some information on these points should be added. He had had a good deal to do with express roads, and he found there were very great advantages in using rails longer than 30 feet, an opinion which he believed was confirmed by experience on all the leading lines in this country. The London and North Western Railway had led the van in the matter of length by using 60-foot rails, and on the Great Western Railway rails 44 feet 6 inches long were being used. The advantage gained was more than that of mere reduction in the number of joints to be looked after: the road was safer and more easily maintained. When the discussion had been going on as to whether longer rails should be used, the great objection brought forward had been the waste which would occur when rails broke, and when faults occurred; but really the number of breakages was so few with the heavy rails now in use that the question of waste on this account could be fairly put aside, because even if a long rail did break it was not necessarily wasted. Another important point connected with the permanent way was that, in his experience, sleepers placed 2 feet 6½ inches apart produced a more easily maintained road on a long line than sleepers placed 2 feet 9 inches or 2 feet 9½ inches apart, as they were on the Great Central Railway. It was well known that the weakest point in permanent way was the bearing of the sleeper upon the formation. That was the point which gave out soonest, and smooth running was dependent on the diligence and the ability of the permanent-way men to pack up the slack at that point where depressions occurred. His experience in a very definite way, trying it first experimentally and afterwards as a practice, had been that the small change of putting the sleepers even 3 inches closer together had had a wonderful effect in getting over that point at which apparently in many parts of the line the impact of the passing engine and carriages had been enough just to indent the sleepers somewhat into the formation. Of course there was also the shorter span to be taken into account. He was quite prepared to show in detail that it paid to put the

sleepers somewhat closer than they had been put on the Great Central line. He thought there had been a noticeable absence of reference to money in the Paper under discussion, and he hoped the Authors would give an analysis or statement of the cost in such a way that the cost of the main line could be separated from the cost of the stations, large or small, and particularly the small ones. This information would be interesting to members who had to deal with main lines, and he thought the omission could be easily rectified. The question of the island station-platform was very interesting, because it followed from the adoption of a central platform that the working of the line when it was doubled, that was when four lines were laid instead of two, would more than probably be by two up lines and two down lines. As the members were aware, there were many long lengths of express lines where there were four lines worked with two up and two down lines. The designers of the Great Central Railway and the traffic-officers of the company had decided that if anything was to be done it would be in the way of two up and two down lines; and he was bound to say that in that case he agreed with them. In this as in many other matters, particularly the question of the accommodation at such a station as Nottingham, or the question of the best arrangement of sidings at such a place as Annesley, so much depended upon the traffic at those particular points that it was very hard to criticise the proposition as a general principle. But with regard to smaller stations perhaps it was not so difficult. In his judgment the question of whether the two up and two down lines in a four-lined road should be adjacent depended entirely on the character of the traffic. He could imagine circumstances under which it would be wise to adopt such an arrangement, viz., where there were few junctions. On the other hand, the arrangement of alternate up and down lines had advantages where it was possible to deal with local and goods traffic on one side of the railway, and to leave the other two lines freer for the passage of express trains. He was greatly interested in the question of end and side tipping, because it so happened that his company were making the South Wales direct line, where there were very heavy banks, and that question had forced itself on his attention. The conclusion he had come to was that, if it was prescribed and arranged that the lift in a high bank should not be excessive, he would be inclined on the whole to prefer going on with the end-tip wagons. He thought it was easy to overdo either end tipping or side tipping by making the lift too high, but if the work was carried out in layers, as it were, the Mr. Inglis.

Mr. Inglis. result would be satisfactory. He was quite sure that whether the bank was to stand or to be troubled with slips depended a great deal on the uniformity of the material of which it was formed. He had in his mind a very high bank with which, except in one part, there had been no trouble whatever. That bank had been tipped in lifts of about 20 feet, and it had been possible to trace the trouble which had arisen at one point to the material which was tipped having come from an unsatisfactory part of the excavation. The question of the treatment of banks also depended very much indeed on local circumstances and on the material dealt with. The line he had referred to was being laid out with curves of 1 mile radius. Every day trains passed over 25-chain curves at a speed of 60 miles per hour, but he thought no one would say that was a satisfactory practice. The principal point which he looked at in a curve of 80 chains, or 1 mile, radius was, that it was not quite fair to the drivers of express trains to provide unnecessarily sharp curves. His experience was that uniform speed could not be obtained from the engine-drivers when they could not see ahead. One man would go full speed ahead and another would not; but if the drivers could see a fair distance in front there was greater uniformity in the running at a high speed, and he thought that was a point which should not be lost sight of. In going at a mile a minute, no sooner did an engine-driver sight a signal than he was close upon it. He quite agreed with Mr. Galbraith about the necessity for having straight lines between the curves. He had a case in which numerous complaints were being made about the travelling and jolting on a line, apart from the permanent way, and the curves there had been examined. There was no curve with a less radius than 30 chains; the majority of them were 40 chains; and the unsatisfactory running on that line at a fairly high speed was solely due to the fact that it was set out without any straight between the reverse curves. He was satisfied that the trouble had arisen entirely from want of precaution on the part of the engineer in not having, say, twice the length of the train between the reverse curves.

Mr. Bidder. Mr. F. W. Bidder, in reply to the Discussion, said that details of the methods adopted for the support of the buildings tunnelled under at Nottingham had been asked for; but as no particular system had been used throughout the work it was difficult to give anything like a complete description of the various methods employed, each case as it occurred having had to be treated in a manner suited to its requirements. The depth from ground surface to the crown of the tunnel varied between 8 feet and

20 feet, and the springing of the arch was on the solid rock throughout. A large number of rock cellars under the houses, of various shapes and sizes, had been cut through, and these had been first of all carefully located, measured and plotted on the working-plans, levels being also taken so that before tunnelling operations were commenced each particular case could be well considered and the necessary steps could be taken to insure the safe upholding of the buildings above while tunnelling was in progress. Where brick walls and sand-rock piers had had to be supported, small holes had been first cut, through which timbers had been inserted and temporarily supported upon the cellar-floors, clear of the space required for the tunnel crown-bars, the brick-work or rock-pier being then tightly wedged up off the timbers. As the lower portions of the brickwork and sand rock had been gradually taken away, other and larger timbers had been placed in various positions, so as to enable them to be supported upon the crown-bars as they were put in the length of tunnelling being excavated at the time. When the excavation had been completed down to springing level, the building of the arch had been commenced, care being taken to wedge up the timbers off the brickwork as it proceeded and before the crown-bars had been struck. In this case the crown-bars had not been put high enough to allow of their being drawn after completion of the brickwork, as was the case with ordinary drawing-bars, but had been kept down within 9 inches of the soffit of the arch, so as to clear the ribs and lagging, and consequently they had had to be removed as the brickwork proceeded. The reason for adopting this method had been to minimise the unavoidable interference with the buildings above the tunnel, and also in some cases to preserve as much of the solid rock over the crown of the arch as possible; as where ordinary drawing-bars had been used the excavation had had to be taken out considerably larger than had been actually required to take the arch. It would thus be understood that it had been very necessary to carefully transfer the weight upon the timbers carrying the walls and piers of the houses off the crown-bars and on to the brickwork as each successive bar had been worked up to. This had been accomplished by means of temporary brick piers and timber packings. When the brickwork of the arch had been completed for some considerable time—generally varying between three weeks and a month—and after the centering had been removed and the arch had taken its proper bearing, the under-pinning of the cellar-walls and rock-piers had been proceeded with, brickwork in cement mortar being used, resting on the Mr. Bidder.

Mr. Bidder. extrados of the arch which had been prepared (by means of projecting rings of brick so as to form a level seating) to receive it, the timber previously supporting the buildings having had to be constantly changed and cut away in small pieces as the brickwork had been put in, an operation which had necessitated great care and a considerable amount of labour. In some instances, where the old buildings had been pulled down for the purpose of reconstruction, the cellars which were to be cut through had been treated in a different manner from those previously described. After a careful survey had been made and the levels taken, the centre line of the railway had been laid down on the cellar-floors and the levels of the extrados of the arch had been fixed approximately. A dummy centering in weak lime concrete had been then formed, the cellars being afterwards filled in with cement concrete to a depth sufficient to form a good foundation for the buildings. Tunnelling had then proceeded and the arch had been built up solid to the underside of the cement concrete already put in and formed to receive it, the lime concrete composing the dummy centering having been removed as a part of the excavation.

The use of several courses of dry bricks in the bottom of wet foundations, where pumping was necessary, had also been referred to. By the adoption of this plan, which had been found both useful and effective, the concrete when put in position was kept above the level of the water by the courses of bricks, which allowed the water to flow freely through the open joints towards the pumps without in any way touching the concrete. The number of brick courses required depended upon the quantity of water to be dealt with, but was usually three or four, as allowance had to be made to avoid as far as possible the water rising in the foundations during temporary stoppages of the pumps from reaching the level of the concrete.

Comment had been made upon the fact that the tunnels approaching the Nottingham Joint Station had been constructed for two lines of way only; but this was a question which had received every consideration in laying out the line. The present tunnels ran as far as possible under the streets of the city, thus avoiding the cost of purchasing a considerable amount of valuable property, and there would be no great difficulty in providing an additional tunnel alongside those already existing, should it at some future time be considered desirable. Mr. Parry had long ago suggested the construction of a short loop line outside the city, over which the through traffic could be conveyed, and which would in all probability be found less expensive and more satis-

factory in working than duplicating the existing tunnels, as not only the tunnels but the station as well would be relieved of this traffic, and delay would be avoided in passing through the city. Mr. Bidder

Attention had also been drawn to the manner in which the down sorting-sidings at Annesley had been arranged, and the objection to the wagons having to shunt back into the departure sidings, instead of travelling forward as on the up side, had been pointed out. This, of course, had been well understood, and the plans originally prepared for the gravitation sorting-sidings, which had been intended in the first instance to be placed at Ruddington, a few miles south of Nottingham, had showed both the up and the down sidings arranged so that the traffic could be worked right through from end to end in its proper direction, the land at Ruddington admitting of this being done without the necessity of constructing any very large earthworks. To meet the requirements of the traffic department, Annesley had been afterwards selected as a more convenient position for the sidings; but the natural fall of the ground towards the south at this place had prohibited the adoption of the arrangement originally intended, and the sidings as now laid down had been considered most suited to the altered situation. As the final quantities and accounts were not settled, it was impossible at the present time to give a definite analysis or statement of the cost of the works, arranged in such a way that the cost of the main line could be separated from the cost of the stations.

Sir Douglas Fox, President, said that, as his son was not present that evening, he might be allowed to say a few words by way of reply. The question about side tips *versus* end tips had been one of very great interest in connection with that particular railway. The work was certainly entered upon with a prejudice against side tipping, and it was only allowed to be introduced with considerable caution; but he must say that, as far as he was concerned personally, he was a convert to the use of side tipping under such precautions as had been mentioned by Mr. Middleton and in connection with embankments of such very large size. Certainly the results obtained went to prove that, properly carried out, it did not lead to more slipping than took place in connection with end tipping. It was found, as Mr. Middleton had stated, that the speed at which the work could be executed was very greatly enhanced. It required however to be laid out on a proper principle. If it were carried out in a careless way it might produce great mischief, but as it was carried out by Messrs. Walter Scott and Company and the other contractors engaged in the work, he could only say that the results The President.

The President. had been quite satisfactory. With reference to the use of burnt clay for ballast, that was also a matter about which great hesitation was felt. One or two of the members had spoken that evening of the extensive use of that kind of material in India, with the practice in which country he was well acquainted; but they had not mentioned one particular factor which had to be dealt with in this country, and that was severe frost. He thought that, at any rate for ballasting purposes, burnt clay required to be used with very great caution, and to be thoroughly well burnt, which was not always an easy thing to secure: it should be burnt to a clinker as far as possible, and should be covered up, if possible, from the action of frost. Thus treated he thought it made very fair ballast where nothing better could be obtained. As far as possible on the Great Central Railway either slag, or, in some few cases near stations, granite had been used, but that was a luxury which the Company could not indulge in to a great extent. They had been obliged to use a certain amount of burnt clay, and had found it on the whole turn out satisfactorily. He was rather glad that Mr. Galbraith had made the remark with reference to the entrance into London. Perhaps Mr. Galbraith was not aware that that particular subject was coming before the Institution—probably next session—in the shape of another Paper, to be contributed by two members, in which the whole of the metropolitan arrangements in connection with the Great Central Railway were to be dealt with, the present Papers dealing only with the country portion of the railway. But he would like at once to tell the meeting that the question of the necessity of four lines into London had in no degree been lost sight of in all the arrangements that had been made. An endeavour had been made to secure a thoroughly good entrance into the terminus with seven lines of rails from Lord's Cricket Ground—where it was felt it was important to get all that possibly could be got while there was a chance. Beyond that at present there was only a 27-foot tunnel with a double line through to the Finchley Road, but the company had purchased the property for the additional two lines, and all the arrangements were made in connection with the tunnel, which was so constructed that the second tunnel could be easily and economically made alongside of it, the skew-backs of the central pier being arranged specially for that purpose. The matter had therefore not been lost sight of; and, at any rate as far as London was concerned, it had been not only foreseen but specially provided for. With reference to the question of curves, there was a 60-chain curve at Rugby, where it had been necessary

The President.

to put one in because the main line itself was on a curve, and in arranging for an island platform it was not possible to do with less than 60 chains. He thought the difference between this and an 80-chain curve could very well be detected if it was noticed while travelling in a fast train. There were few trains which did not stop at Rugby, but some ran through that station, and it would be found that the trains did not take the 60-chain curve as sweetly as the 80-chain curve. It was beautiful to see a fast train pass one of those island platforms round the reverse curve of 80 chains, with a proper tangent between the two curves. He would like to refer to the question of tangents between curves, because, although in this country it was thoroughly understood, foreign engineers often introduced great difficulties because they insisted upon too great a minimum length of tangent. He had had a case recently where it had been very important to lay out a line of railway round sharp spurs of mountains, and he had been bound by a law of the Medes and Persians, laid down by certain French engineers who exercised government control there, that very long tangents should be used between the reverse curves. That had made it impossible to lay out any line of an economical nature in passing round those spurs. Tangents were necessary, but without proper care they could be carried to too great a length. With regard to the permanent way, the extension to London had been laid with the company's standard permanent way. No special design had been made for it. On the question of concrete walls, referred to by his old friend Mr. Johnson and others, he quite agreed that it was of great importance, in building a wall of that kind, not to leave off at night with a smooth surface, but either to leave some of the plums exposed so that they might form a key to the next day's work, or to step it, as was mentioned by Mr. Robertson, and thus make quite sure that there would be no tendency in the work to slide on its base. He thought he had met, as far as he had been able in the time at his disposal, the main questions raised that evening, and he could only thank the members for the way they had received the two Papers. He hoped they would be able next session to hear the Paper describing all the terminal arrangements of the Great Central Railway in London.

Correspondence.

Mr. Collinson. Mr. A. H. Collinson could not altogether agree with Mr. Bidder's statement that no great difficulty had been experienced in dealing with the earthworks—at any rate, so far as contract No. 3 was concerned, on which he had been at that time Resident Engineer. This contract practically commenced with an embankment 3 miles 16 chains in length, containing, with the widening for the station-yard at Whetstone at its northern end, upwards of 850,000 cubic yards of earthwork, or very nearly one-half of the whole available excavation on this section of the line, which was nearly 16 miles in length; about two-thirds of the whole quantity being contained in the first mile from the Whetstone end of the bank. The construction of this embankment had been attended by very considerable difficulties, owing primarily to the necessarily long lead, which had involved bringing a considerable portion of the material from cuttings 12 miles distant, and for the first 6 miles from the south up a rising gradient; and, secondly, to the numerous obstacles which had had to be either temporarily or permanently bridged over before continuous tipping could proceed, these including the Union Canal, the Midland and London and North Western railways, nineteen main and public roads, various rivers, streams and accommodation roads, and a viaduct over the valley of the River Seuce at Whetstone. According to the conditions of the contract, special provision had had to be made by the contractors for the rapid formation of this embankment. The work had been carried on continuously, day and night; the time occupied from the commencement to completion had been 18 months, being an average rate of 1,800 cubic yards per 24 hours, not allowing for bad weather, holidays, &c. The high portion of the bank at Whetstone had been tipped in three lifts; no side tipping had been allowed towards the toe of the work; and the slopes where the height of embankment exceeded 20 feet were compound, being 3 to 1 at the base, then 2½ to 1, and 2 to 1 at the summit. Several considerable slips had occurred in this embankment, which had undoubtedly been attributable to some extent to the cause assigned by Mr. Bidder, viz., heavy rains following remarkably dry weather; but they had also been due to the practically unavoidable variations in the material forming the whole. In all cases these slips had been permanently cured by what might

be described as arched counterfort drainage, consisting of a series of hand-packed granite rubble drains or counterforts, taken to the base of the slip, in some instances to a depth varying between 50 feet and 25 feet into the bank, and ranging in width between 3 feet and 12 feet, placed at intervals in the slips as required; in most cases a distance of 33 feet from centre to centre had been found to be suitable and convenient. These counterforts were connected by arches placed at intervals down the slope, the arches taking the place of the usual V-shaped drains or feeders, to which he considered they were far preferable, both as regards utility and appearance. Special provision was made for drainage by pipes at the base, the ordinary side ditch being filled in. In cutting No. 38, a deep layer of very wet running sand had been met with, outcropping about 15 feet above formation-level, and underlying the boulder clay; and very considerable care had been required in getting out the lower lift, to prevent the upper slopes from slipping. Deep trenches had had to be excavated and filled in with rubble to drain the sand, while breastwalls had had to be built to the underside of the clay. North and south of Watling Street, the sidelong ground forming the base of embankment No. 49, 65 chains in length, and the site for a future station-yard, had consisted, for an average depth of 12 feet, of water-logged peat. The whole area had had to be most carefully drained and benched before any tipping could be commenced. In connection with the drainage of the earthworks on this contract alone, 35 miles of glazed earthenware pipes of diameters varying between 4 inches and 18 inches, had been required, and upwards of 50,000 tons of granite rubble in trenches, counterforts, &c. The settlement of a bridge of 12 feet span and of the adjoining embankments at Bulwell, due to the coal-workings, had been first noticed in 1893. It had affected a considerable area of land and a length of 1½ mile of the railway, the maximum subsidence, 3 feet 6 inches, occurring in the centre of this length where the bridge in question had been built. The subsidence had been gradual and very uniform until the latter end of 1897, when it had ceased altogether. No cracks or other signs of any description were perceivable on either land or buildings, and it was only by use of the level that any settlement could be detected. The bridge at mile 5 did not show the slightest sign of fracture, the abutments remaining perfectly vertical. This was due, no doubt, to the large area of ground affected. Mr. Collinson.

Mr. JOHN PRICE observed that side-tip wagons had been designed at the end of the year 1880 by Mr. D. Connery, M. Inst. C.E., who was then acting as Engineer to the late Mr. T. A. Walker, Mr. Price.

Mr. Price. and had been first used in the construction of the Swansea East Dock (afterwards called the Prince of Wales Dock) for the purpose of tipping dock-excavation to form quays, conveying and distributing ballast for permanent way, and tipping concrete from a timber gantry for the construction of the Swansea East Pier, carried out under the superintendence of the late Mr. James Abernethy, Past President, as Chief Engineer. The wagons used for the concrete had been smaller than the others, being constructed to hold about $2\frac{1}{2}$ cubic yards each. The whole of the concrete in the East Pier, about 11,000 cubic yards, had been tipped from them. The original design for these wagons had been on the rocker principle, the centre of the rocker being made to coincide with the centre of gravity of the tipping part of the empty wagon. This had insured that, as the wagon-body had been rolled on the rockers, the centre of gravity had moved in a horizontal line, and consequently the operation had required no more force than was necessary to overcome the friction, which was very small. As the centre of gravity of the wagon when loaded had been above the centre of the rocker when the wagon was in its normal position, and about three inches lower when it was rolled over and was just on the point of discharging its load, it followed that it had moved along a falling incline as the wagon was being tipped. It had thus required only the unfastening of the catch at the back, and a very slight lift, to tip the full wagon, and when the contents had been discharged the empty wagon had only required sufficient force to overcome the friction of the rollers and guides to bring it back to its normal position. If it had been considered desirable the centre of the rocker could have been so taken with respect to the centre of gravity that the empty wagon would of itself have returned to its normal position as soon as it had discharged its load. In the original design already referred to the length over buffers had been 9 feet, that of the wagon-body being 8 feet, the width had been 6 feet and the depth 2 feet, the capacity being consequently about $3\frac{1}{2}$ cubic yards. The top of the wagon had been 6 feet $1\frac{1}{2}$ inch above the rails, and the wagon had tipped to an angle of 60° with the horizontal. The guides in this design had been attached to the rockers and wagon-body, the guide-pins being fastened to the bottom frame. The guides had been therefore involutes of circles, and when properly made had scarcely touched the guide-pins in the process of tipping. In the side-tip wagons on the rocker principle made for Mr. Walker in 1882 at the Severn Tunnel works, the guides had been altered so as to be attached

to the bottom frame, the pins in this case being attached to the wagon-body, and the grooves in the guide-plates being cycloids instead of involutes of circles as in the original design. During the construction of the Barry Dock and Railways between 1884 and 1889, some of the details, especially the dimensions, had been modified, the size then adopted being 9 feet 10 inches long, 6 feet 1 inch wide, and 2 feet high clear inside, the capacity thus being about $4\frac{1}{2}$ cubic yards. The height from rails had been 6 feet 2 inches, and the tipping angle 47° with the horizontal. These wagons had been used on the whole of Mr. T. A. Walker's contracts since 1880. At one time Mr. Walker had had about 4,000 of them on the Ship Canal contract alone, and almost the whole of the material in the large embankments for the railway deviations had been tipped from them. Mr. Price had built about 120 of these wagons within the last fifteen months for use on the Crowhurst, Sidley and Bexhill Railway. In their construction correct principles had been kept in view with reference to the centre and radius of the rockers and the proper shape of the slot guides, with the result that the wagons were better balanced than those used on several contracts where these points had not been attended to. The wagons rode quite level without showing any signs of leaning over, and they tipped easier than any Mr. Price had previously met with. Mr. Price.

Mr. J. W. TWINBERROW suggested that if the line had been taken through Northampton that town would have obtained more direct communication both north and south, and the local traffic by the Great Central Railway between Leicester and Northampton might have proved as satisfactory as that between Leicester and Nottingham had already become. As clay was plentiful throughout the country traversed, and stone was almost entirely absent, it seemed a pity not to have made use of burnt ballast on a more extensive scale. The amount of ballast used during the contractors' maintenance and subsequently showed that on the banks practically the whole of the ballast first laid would at the end of three or four years have worked down below formation-level. Under these circumstances its quality was not a matter of much moment, whilst the work would have been cheapened and the progress greatly expedited by the unrestricted use of burnt ballast on all banks. In excavating for the viaducts through the town of Leicester numerous Roman foundations had been brought to light. In most of these a very liberal use had been made of burnt ballast or broken-brick rubbish similar in appearance to the ballast burnt from the Leicestershire Lias clays. In some cases it had been punned in Mr. Twinberrow.

Mr. Twinberrow. layers under pavements and showed no signs of deterioration. In others it had been found mixed with a large proportion of lime and very little sand to form a compact and durable concrete. Its condition after 1,700 years had a complete justification for the confidence which the Romans had evidently felt in the free use of their most plentiful local material. Better instances of the suitability of burnt ballast for cement concrete could not be adduced than the retaining walls on the Great Northern Railway constructed by Mr. Richard Johnson in the neighbourhood of London. These were composed of 5 parts of burnt ballast and 3 of Thames ballast to 1 of Portland cement. No excessive precautions had been taken in burning the ballast, it had been left in the heap long enough to cool thoroughly, and had been screened before using. He knew of no instance in which the concrete had failed. A concrete composed of 8 parts of burnt ballast to 1 of Portland cement had also been tried in foundations and spandrels. This had been an interesting experiment, but had been only moderately successful. On the question of side *versus* end tipping there could be no two opinions as to which was the more expeditious. When steam-navvies were employed, the emptying, not the filling, of the wagons determined the rate of progress. With three end-tip roads it was often difficult to keep the middle of a 30-foot bank well filled up. If the work on a bank were not arranged to proceed fairly continuously slips might result whichever system was adopted. When a steep incline had been formed in order to tip a bank with a bottom lift of not more than 20 feet, a slip might be expected on tipping the next lift over the top of this steep incline. In view of the increasing length of express engines, he thought a longer turntable than 50 feet might have been adopted with advantage. The question of long bogie wagons of high capacity was also coming inevitably to the front, and he thought the Great Central Company would have been able to work their mineral traffic at considerably less cost than their competitors had they laid out their yards with a special view to the accommodation of such wagons. The advantages of a greater rail-length than 30 feet were also now generally recognised. With regard to the ingenious outside check-rails on the long girder spans, if the outside rails had been continued for some distance beyond the span, gradually receding from the running-rail and dropping down to sleeper-level (instead of terminating abruptly a few inches from the rail), they would have tended to rerail a derailed vehicle when approaching the bridge. In their present position he thought they were much more likely to complete

the wrecking of the train at the very point where it was most essential to avoid it. In view of the fact that the dead load on the driving-axles of modern locomotives already amounted to as much as 19 tons, and that the counterweight for the reciprocating parts was usually in English practice concentrated in a single pair of wheels, provision for a dead weight of 20 tons in designing the bridge-floors, etc., hardly appeared adequate, although the low stress allowed throughout the steel-work, viz., 5 tons per square inch, no doubt provided the necessary margin of safety. Mr. Twinberrow.

Mr. F. DOUGLAS FOX, in reply to the Correspondence, remarked that on the Southern Division from Rugby to Quainton Road, burnt ballast had been used very extensively on high embankments as bottom ballast, the top ballast (broken slag) being reserved until the close of the period of maintenance, allowing a good time for settlement of embankments, etc. The specification had been:—"Embankments of 9 feet in depth, and upwards, to be bottom ballasted with hard clinker-burnt clay ballast, screened if necessary." The following Tables gave particulars of allowance for impact in designing the bridges:— Mr. Fox.

Span.	Per Cent.
5 feet to 15 feet .	50
15 " " 25 " .	40
25 " " 35 " .	30
35 " " 45 " .	20
45 " " 55 " .	10

The factors for steel when the above percentage was added were:—

Description of Stress.	Tons per Square Inch.
Compression. . .	5·0
Tension	6·5
Shearing. . . .	5·0
Bearing	8·0

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27 March, 1900.

Sir DOUGLAS FOX, President, in the Chair.

The discussion on "The Great Central Railway Extension" occupied the evening.

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3 April, 1900.

SIR DOUGLAS FOX, President, in the Chair.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

George Reginald Bayliss.
Thomas Clark Deverell.
Frederic Gleadow.
James William Helps.
George Bastable Laffan, B.E. (*Queen's.*)
Ernest Lawson Mansergh.
Frank Chittenden Osborn.
William Robinson, M.E. (*Royal*).
Arthur Keen Smith.
Charles Edward Stewart.
Herbert George Sumner.
John Joseph Whiteley.
Joseph William Wilson.
Hugh Copner Wynne-Edwards.

And that the following Candidates had been admitted as

Students.

Charles William Allott.
Edward Saunders Allsup.
John Charles Antinori.
Reginald Edward Vere Argyle.
Harold Cholmley Mansfield Austen.
William Henry Ballantyne.
Alfred Thomas Best.
Benjamin Hall Blyth, Jun.
Charles Valentine Boulton.
Cecil Gustav Bradley.
Frank Broomfield.
Walter Burn.
Hugh Campbell.
John Colet Collett.
Harold Collins.
Edward Ayerst Davies.
Frederick Thomas Ecroyd.
Ernest William John Edwards.
Henry Arthur Rolleston Edwards.
Horace William Ellis.
Edward George Fenning.
William Noël FitzGibbon.
John Wilgress Goldson.
George Francis Carter Gordon, B.A. (*Cantab.*)
Henry Algernon Hampson.
Thomas Blackburn Hennell.
John Julius Irvine Jameson.
Samuel Ross Jameson.
Edward Clinton Jansen.
Harry Oscar Johnson.
John Johnson.
Frederick Lawrance.
Archibald Leitch.
Sydney Evan Lowsley.
Richard Charles Montague Luke.
Arthur Henry May, B.A. (*Cantab.*)
Harry Middleton.
Enrico José Pereira de Moraes.
Charles Dearne Pearson.
James Barclay Peat.

Students—continued.

ROBERT RUSSELL.
JAMES ALBERT SEAGER.
JOHN DUDLEY STUART.
JOHN VICK THOMAS.
EDWARD HORACE THOMPSON.
MITCHELL HENRY UPTON.
GEORGE WALKER.
ROBERT WILLIAMSON WALKER.
THOMAS ARCHIBALD WALKER, B.A. (*Cantab.*)
HAROLD WALMSLEY.
ARTHUR FELIX WEDGWOOD.
ALFRED WHITTINGTON-COOPER.
JOSEPH DOUGLAS WILSON.
JAMES BERKELEY WISE.
WALTER HARTLEY WISWALL.
PETER REMUS WRAY.
ROMULUS PAUL WRAY.
FRANK WRIGHT.
FRANK WILSON WRIGHT.

The Candidates balloted for and duly elected were: as

Members.

ROBERT CAIRD.
ARCHIBALD DENNY.
ROBERT SUMMERSIDE WILLIAMSON.

Associate Members.

EDWARD BAZALGETTE, Jun.
EDWARD LEIGH BENNETT.
CHARLES JOHN BROWN.
JAMES BROWN.
HARRY CLEGG.
CHARLES HENRY COLE.
LEONARD GEORGE FELKIN.
DAVID JOHNSON GADSBY.
GEORGE GARRARD.
NICHOLAS GEORGE GEDYE, Stud. Inst. C.E.
GEORGE HENRY GIBSON.
GEORGE GONSALVES.
TOM SHIRLEY HAWKINS.
HARLEY HECKFORD.
ALBERT STEWART HUME.
LOUIS JOHN HUNT, Stud. Inst. C.E.
WILLIAM EDWARD HUSTON.
ALFRED ERNEST JACKSON.
WILLIAM HENRY JAMES, B.Sc. (*Wales.*)
THOMAS BOWEN JEX-BLAKE, B.A. (*Oxon.*)
WILLIAM HENRY CORYTON KEMPE.
WILLIAM HENRY GUSTAV KIESER.
RALPH MORGAN LEWIS.
WILLIAM NEWSAM MCCLEAN, M.A. (*Cantab.*), Stud. Inst. C.E.
ARTHUR CECIL MACKENZIE.
EDWARD HAROLD MORRIS, Stud. Inst. C.E.
CHARLES HENRY NAYLOR.
THE HON. GEOFFRY LAWRENCE PARSONS, B.A. (*Oxon.*), Stud. Inst. C.E.
ALGERNON PEAKE.
STANDEN LEONARD PEARCE.
REGINALD GODFREY PECKITT, B.A (*Oxon.*)
NEIL JAMES PETERS.
GILBERT ROSENBUSCH.
THOMAS ROY.
CHARLES PHILLIPS SANDERS, Stud. Inst. C.E.
WILLIAM SHARPE, B.Sc. (*Glas.*)
GEORGE HENRY SMITH, B.A.I. (*Dubl.*)
FREDERICK SOUTHEY.
HERBERT JAMES STRACEY.
WILLIAM FREDERICK STUART-MENTETH.
GEORGE THOMSON.
WALTER EDWARD THORNHILL.
RUSSELL TIPPETTS, Stud. Inst. C.E.
JOHN HENRY WHITE.

An Associate.

REGINALD ERNEST PICTON, *Captain R.E.*

(*Paper No. 3193.*)

"Economical Railway Construction in New South Wales."

By Henry Deane, M.A., M. Inst. C.E.

In order to develop the resources of the colony of New South Wales, where, owing to the arid nature of the climate, the value of produce per acre is comparatively small, railways of an economical character have long been felt to be necessary. The vast areas devoted to pastoral pursuits, although producing wool of the highest quality, can support but a small number of sheep per square mile. The average area required to feed a sheep in New South Wales is 3 acres, while in the driest parts on the western side of the Darling River as many as 10 acres are required for each sheep, and the distances to be travelled for the collection of a given quantity of produce are consequently very great. Extensive areas just over the western slope of the dividing range are now being devoted to the cultivation of wheat, and here again, in order that freight may be reduced to as low a figure as possible to meet the competition of imported wheat, the interest on capital cost requires to be brought down to a minimum. It is clear, however, that a break of gauge is to be avoided.

The present system of economical construction on the standard gauge is the outcome of gradual changes in the design of the permanent way, which have taken place since the commencement of railway construction in New South Wales in 1853. The first lines constructed, those between Sydney and Parramatta, and between Newcastle and Maitland, were laid with double-headed wrought-iron rails weighing 75 lbs. per yard, resting on 25-lb. cast-iron chairs 3 feet apart, and ironbark sleepers 9 feet long by 10 inches wide by 5 inches thick. The top of the rail was 2 feet above formation, so that there was a depth of 12 inches of ballast under the sleepers, Fig. 9, Plate 5. This construction of permanent way was continued for the extension to Picton on the southern line, and Penrith on the western line, and also between

Newcastle and Singleton on the northern line, except that the depth of ballast on the latter was slightly reduced. At Penrith and Picton the foot of the dividing range may be said to have been reached; and at this point difficulties began, Fig. 1, Plate 5.

The dividing range of New South Wales stretches from north to south of the colony at a distance from the coast varying between 50 miles and 120 miles. On the east the streams flow to the Pacific Ocean; on the west the waters are caught in the Darling-Murray basin. The altitudes which have to be surmounted in order to pass from one side to the other vary from between 2,000 feet and nearly 4,000 feet; and some difficulties are caused by the steepness of the eastern slope and its general rugged and broken character. When the railway had reached Penrith and Picton, very strong influence was brought to bear to abandon its extension, and the Government was urged to push into the interior with horse tramways estimated to cost £4,000 per mile. Mr. Whitton, M. Inst. C.E., the engineer-in-chief for railways, stoutly opposed this view, and fortunately was supported by some of the leading statesmen, and by the Governor, Sir John Young. It was eventually decided to continue the railways over the range into the interior, but it was understood that the utmost economy was to be practised for the extension of the western line to Bathurst, and of the southern line to Goulburn. Although the design of the permanent way remained the same, steep gradients of 1 in 30 and 1 in 33 and curves of 8 chains radius were found necessary to keep the expenditure within the limits that had been fixed, and the thickness of ballast under the sleepers was reduced to 6 inches, Fig. 10, Plate 5. The northern line was also extended to Murrurundi with the same class of permanent way.

The railway system having reached Goulburn, Bathurst and Murrurundi, it was soon evident that further extensions were needed, and renewed attempts to reduce the cost of construction were made. The chair road was now discarded, and flat-bottomed rails, resting directly on sleepers, were substituted. The rails were of wrought-iron weighing 70 lbs. per yard, and were fixed with screws and spikes to sleepers of colonial hardwood, not necessarily ironbark, which is the best timber for the purpose, but generally more expensive. The size of the sleepers was reduced to 8 feet by 9 inches by 4½ inches, and the distance from centre to centre was reduced to 2 feet 8 inches. The depth of ballast under the sleepers was 6 inches, and the width of formation in

cutting was reduced to 15 feet. Later, the Bessemer process furnished a cheaper and more durable material than wrought iron, and steel rails weighing 71½ lbs. per yard were substituted, but otherwise the construction remained the same. The principal extensions made on this system were the completion of the northern line to the Queensland border, the north-western line—Werris Creek to Narrabri, the western line to its terminus at Bourke, the south-western line—Junee to Hay and Narrandera to Jerilderie, the southern line to the Murray and its branches to Gundagai and Cooma, the Illawarra and North Shore lines, the Lismore to the Tweed line, the connecting line between Sydney and Newcastle, and the cross-country line from Blayney to Harden, the only exceptions being the extension of the Illawarra line to Nowra, on which the cuttings were increased to 18 feet in width, and two suburban lines which differed in some details.

No great economy in construction had, however, yet been effected. Flat-bottomed rails had been substituted for double-headed rails and chairs, but the latter construction would now be looked upon as an unnecessary extravagance, the flat-bottomed rail being considered as representing the *ne plus ultra* for this colony, and certainly it is the type most suited to the conditions. This is so thoroughly recognized, that on those portions of the main line which have had to be renewed within the last few years, 80-lb. steel flat-bottomed rails have been used. The other economies were reduced ballast, narrowed formation and the use of steep gradients and sharp curves with the object of saving earthworks.

The first attempt to introduce a "light railway" system was made in 1884, when a proposal for a line from Forbes to Wilcannia, 340 miles long, was submitted to Parliament, and a sum of £1,050,000 was voted for the purpose. Steel rails 60 lbs. per yard were to be used, and 11,000 tons of these were ordered from England, and arrangements were made to land them at Port Victor, S.A., in order that they might be taken direct up the River Darling to Wilcannia, so that construction might be started at that end as well as at Forbes. Tenders for sleepers to be delivered at the river were invited. Nothing further was done, however, and the rails, instead of being sent to Wilcannia, were all brought to Sydney and put in stock.

In 1886 the late Sir John Fowler, Past President, visited Sydney and, invited by the Government of Sir Henry Parkes, reported on the question of light railways.

During 1889 there was a lull in railway construction; some

railways were completed and the Hawkesbury Bridge[1] was finished, but no new works were undertaken. There was, however, considerable activity in survey work and several proposals for new railways came under the consideration of Parliament.

In June, 1889, the Author was called upon to take up the responsibilities of Mr. Whitton's office during his absence on leave, which terminated with his retirement from the service and the appointment of the Author as his successor.

In the year 1888 a new administrative system had been introduced. Two Acts were passed, one a Railway Act for placing the construction of railways and the management of the traffic under separate authorities, and the Public Works Act under which all proposals for public works of an estimated value of £20,000 and over, were to be inquired into and reported upon by a Parliamentary Standing Committee, before being generally dealt with by Parliament. The Railway Act provided for the appointment of three Commissioners to control the working, and the late Mr. E. M. G. Eddy, Assoc. Inst. C.E., was selected for the office of Chief Commissioner.

One important improvement in method resulted from the new conditions, namely that instead of railway projects being rushed through Parliament without sufficient consideration, there was now time given for careful investigation, and questions of location, gradient and economy of station-works, had full attention bestowed upon them. The immediate result was that lines, such as that from Molong to Forbes, which had been laid out with gradients of 1 in 40, were eventually constructed with a ruling gradient of 1 in 60 only, and other proposals were modified so that nothing steeper than 1 in 75 and, in most cases, 1 in 100, came to be adopted.

In 1894 the Author visited the United States of America and Europe, paying special attention not only to American methods, but to the light-railway system of Ireland and to the narrow-gauge railways of France constructed to the 60-centimetre gauge on the Décauville system. To the Author the conditions in America, especially in the west, seemed most nearly to approximate to those of New South Wales, and it therefore seemed that the experience there gained would afford the desired type. It was found not uncommon practice to construct the railways in the first place without ballast, and that it was only after the

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 2.

traffic had been well established and means could be furnished out of the revenue of the lines in question, that they were strengthened in various ways, and especially by adding ballast. Many lines in the United States remain unballasted to the present day and may possibly never be ballasted, in some cases because the climate is dry and the formation not liable to irregular subsidence, in other cases because ballasting would be too expensive a work to carry out, owing to the distance over which suitable material would have to be carried.

In New South Wales the conditions are not dissimilar to those of the western United States, and the methods there in use were therefore largely followed. To the west of the dividing range when the more rugged country is passed, the climate becomes drier, the mean annual rainfall decreases to 20 inches or even considerably less, and in some parts the expense of providing ballast is an important consideration. The elimination of ballast therefore results in an important saving. It is clear, however, that such an economy is only applicable where the climate is somewhat arid, as is the case over the whole of Australia, if the seaboard and the more or less mountainous region adjoining be excepted.

Very great care is now bestowed on location, and lines are laid out so that the formation level may follow as nearly as possible the surface of the ground, but be raised a little above it. This principle brings with it other economies such as those in culverts and bridges, which become less costly in consequence of reduction of height and width of embankment.

In the design of the earthworks and permanent way the following rules are observed:—

(1) Wherever the ground admits of it, the railway is carried on a low embankment between 6 inches and 9 inches in height at the crown, and cuttings, even small ones, are avoided if possible. In the first place, an embankment made from side cutting is much cheaper than one made from ordinary cutting, although the deposition of the excavated material from the latter may double the length of formation made under the one operation; and in the second place, maintenance on a bank is much easier than in a cutting; there are no choked water tables to clean out, and the drainage being directed away from the sleepers, these are not liable to get waterlogged.

(2) The formation is at once carefully rounded, so that the water falling on it may readily run off. The embankment is well consolidated by rolling, after which the surface is carefully

trimmed. It has been the practice of the Author to give a fall of 6 inches from the crown of the embankment—that is, from the under side of the sleepers to the edge of the embankment. In America a larger difference is usually adopted.

(3) Ballasting being dispensed with, and the earth forming the embankment being frequently somewhat soft, it is desirable that the sleepers should be sufficient in number to provide a proper supporting area. The size of the sleepers used is 8 feet in length and 9 inches in width, and the Author's practice has been to put fourteen sleepers to the 30-foot rail, the joint sleepers being placed a little closer than the rest. This gives an average of about 2 feet 2 inches from centre to centre.

(4) Selected earth is used to form a mound along the centre of the road between the rails. A space is left clear below the flanges of the rails through which water can run off, Fig. 10, Plate 5.

(5) Care is taken to keep the ends of the sleepers clear of earth, so as to avoid the formation of pits, in which water would collect and splash into the working parts of the locomotive. If the sleepers show a tendency to sink into the bank, the ends must be repeatedly cleared of earth, so that any water tending to collect may drain away.

The rails used weigh 60 lbs. per yard, and the limiting axle load is approximately 12 tons on the two wheels, but this is often somewhat exceeded. The speed of the trains is limited to 20 miles per hour. Sir Benjamin Baker's formula for the relation between the weight of the rail, the load and the speed, as given in Molesworth's Pocket-Book, viz.:—

$$W = 17 \sqrt[3]{(L + 0 \cdot 0001\, L v^2)^2},$$

tends to show that, with the given weight of rail and speed, the allowable wheel load is 6·376 tons, or 12·752 tons per axle, which is greater than what has been actually prescribed.

The sleepers are of a somewhat rougher character than those previously used. The sleeper-getter is allowed to supply his sleepers without cleaning off the sapwood, which is, it is to be remarked, quite useless, as it rapidly decays and eventually disappears. A stipulation is made, however, that there shall be a minimum of heartwood contained, that the latter shall show a thickness of at least 3½ inches at the sides, and that after adzing a width of at least 5 inches of heartwood shall be present as a bearing for the rail. A limit is also placed on the thickness of the sleepers to prevent them becoming too clumsy and costly in carriage. This class of sleeper is technically termed "round-

topped." The price paid varies with the district in which they have to be delivered. In proximity to the ironbark forests 2*s.* per sleeper is a fair price. The average paid, however, has been about 3*s.* per sleeper, the difference being made up in road carriage and railway freight.

The timber used in the interior for sleepers consists of three species of ironbark, *Eucalyptus crebra*, *E. siderophloia* and *E. sideroxylon*, and in the southern part of the colony, or on the chief rivers, "red gum," *E. rostrata*, is used; but, while the ironbark sleepers are split out of the log, red gum must always be sawn, and, although a very durable timber if well selected, it is subject to serious defects, such as shakes and gum-veins. On the coast, besides the three species of ironbark above enumerated, a fourth grows, namely, *E. paniculata*. This is by far the best of the group, and, on account of its valuable properties, is worthy to rank with teak and greenheart.

The methods adopted for carrying out the earthworks are various. A good deal of the country traversed is somewhat thickly timbered, in which case it has to be cleared and stumped, and, owing to the existence of roots, the excavation and filling are done with picks, shovels and barrows, the cost being 7*d.* to 8*d.* per cubic yard.

Where the country is devoid, or almost devoid, of timber, the work is done with ploughs and scoops. The surface of the side cutting is ploughed, and Columbus scoops holding 7 cubic feet, drawn by a single horse, are used. This method has proved to be by far the most convenient and economical. Scoops can be used for filling banks up to 8 feet high, and it has been found that for banks 6 feet high, formed out of side-cutting 3 feet deep, the cost, including the previous ploughing, has not exceeded 4½*d.* per cubic yard. Dray work in short banks, where it is not economical to place the scoop-gang, costs about 9*d.* per cubic yard.

After the embankments have been made up they are trimmed and rolled. Barrow-banks are rolled first with the roller light, and finished with it weighted up to 5 tons. Scoop-banks become consolidated during making, and thus can be rolled at once with the full load.

On the Narrabri-Moree Railway works, which were let by contract, two Austin graders were used. These machines undoubtedly did economical work when continuously in use, but they were frequently laid up, and they were not found suitable except in very long banks of even height. In railways through the class of country now being considered, wagons and wagon

roads are out of the question; there are no large cuttings, and cuttings of any size are avoided where possible.

Besides the reduction in the cost of earthworks, and the saving effected by dispensing with ballast, other methods of securing economy have been looked to. The waterways form an important feature. In the interior the cheapest efficient material out of which these can be made is ironbark timber. Where steep gullies are intersected, concrete culverts would probably be more suitable, but against the use of this material is the cost due to freight over long distances and to the quantity that would have to be used to provide solid foundations in somewhat soft ground. These waterways, Figs. 2–6, Plate 5, are all designed to take the heaviest class of engines.

Economy is also secured through the design of the station buildings. These are built of wood, largely of local cypress-pine (*Frenela*). They are very cheap, may be expected to meet the requirements of traffic for many years, and can be easily added to; or if at an early date they are found entirely inadequate in accommodation, there is not much expenditure wasted if they have to be superseded by more commodious buildings. An example of a cheap terminal passenger building is given in Fig. 8, Plate 5.

One economy that was introduced, namely the abolition of high platforms and the substitution of "landings" only 9 inches above the rail, has now been abandoned, as it was unsuited to the older passenger rolling stock which, as a matter of convenience, is generally used on the branch lines. The station yard at Condobolin is a fair sample of a country terminal station to the latest design in New South Wales, Fig. 7, Plate 5.

Public level-crossing gates have been dispensed with, and the concomitant expenses of building gatekeepers' cottages and paying gatekeepers have thus been avoided. In substitution, cattle-pits—sometimes called cattle-stops—are placed under the line at each side of roads, with grids on the top to prevent cattle straying on to the private property on each side. The side fences are run into these, and warning boards, facing both ways, are erected.

In most cases the traffic on these lines is carried on in daylight only, running at night being almost entirely avoided; fencing has in consequence been dispensed with, and a saving of about £100 per mile has been effected. At the intersection of cross fences, cattle-pits are built under the line to prevent stock from straying from one side to the other. Occupation-crossings with gates are rendered unnecessary. On the Jerilderie to Finley line, the railway runs alongside the road, with no dividing fence.

The first of the country lines carried out under the new system was the Narrabri-Moree Railway, 63 miles long. The designs showed an unballasted road. As, however, for the greater part of its length it traversed "black soil," which in dry weather becomes very friable on the surface, and in wet weather is reduced to pulp, the Author decided that a certain quantity of ballast should be dropped on the formation for maintenance. In spite, however, of the peculiar character of this "black soil" the Author is of opinion that owing to the generally arid condition of the surface the want of ballast would have caused no danger and no difficulty, unless, which is very rarely the case, wet weather extended over a period of many days. Since this railway has been opened for traffic, business has so largely increased, that it has been considered desirable to strengthen and improve the line by adding more ballast and increasing the station-accommodation. The total cost of construction, however, is still under £145,000, equal to £2,301 per mile.

Four other railways have been constructed on the new method and are destitute of ballast except in the station-yards. These are:—

—	Length.		Actual Cost.	Cost per Mile.
	Mls.	Chs.	£	£
Jerilderie to Berrigan	21	65	74,750	2,107
Berrigan to Finley	14	24		
Parkes to Condobolin	62	60	117,669	1,875
Nevertire to Warren	12	33	36,066	2,907

Two railways are in course of construction:—

—	Length.		Estimated Cost.	Cost per Mile.
	Mls.	Chs.	£	£
Tamworth to Manilla	29	49	73,170	2,534
Moree to Inverell	96	35	279,500	2,898

Three railways have been authorized in addition to the above, and the work of construction will be commenced at an early date:—

—	Length.		Estimated Cost.	Cost per Mile.
	Mls.	Chs.	£	£
Byrock to Brewarrina	58	43	146,350	2,500
Koorawatha to Grenfell	32	22	96,825	3,000
Rock to Lockhardt	25	13	65,939	2,621

The four extensions first mentioned have now been opened for traffic some time, and give an opportunity of forming a judgment as to the value of the principle. The maintenance, which is under the charge of Mr. T. R. Firth, M. Inst. C.E., costs about £30 per mile, the practice being to divide the lines into sections of 10 miles or 12 miles, with three men on each section. Each gang is provided with a tricycle and a Sheffield trolley.

The following is the original estimate of cost of the Parkes to Condobolin Railway, from which the relative value of the different works involved in the construction of a line of this character may be seen. The works on this line were carried out by contract, with the exception of a small work in connection with the water-supply at Condobolin.

ESTIMATED COST PARKES TO CONDOBOLIN RAILWAY. (Length 60 miles 30 chains.)

—	Estimated Cost.			Cost per Mile.
	£	s.	d.	£
Earthworks	18,112	10	0	300
Culverts and bridges	7,245	0	0	120
Fencing, say one-sixth required	1,026	7	6	17
Level crossings, stops, gates	3,622	10	0	60
Permanent way materials	38,036	5	0	630
Laying at 1s. 6d. per yard	7,969	10	0	132
Ballasting station yards and soft places only	3,984	15	0	66
Sleepers	18,112	10	0	300
Total for running road	98,109	7	6	1,625
Station works and sidings, water-supply tanks, etc.	12,890	0	0	213
Mileage posts and signboards	905	12	6	15
	111,905	0	0	1,853
Engineering and supervision about 5 per cent.	5,614	17	6	93
	117,519	17	6	1,946
Contingencies nearly 8 per cent.	9,297	15	0	154
Total . . . £	126,817	12	6	2,100

The final location of the line brought up the length to 62 miles 60 chains, but the total expenditure has not exceeded £117,669, or £1,875 per mile. This includes the erection of telegraph and instruments, which the Railway Commissioners at first thought could be dispensed with. It is possible that the capital expenditure may eventually be brought up to the estimated amount, as owing to the difficulties in some cases of foreseeing what waterways should be provided, formulas being entirely inapplicable, additional openings to the value of a few thousand pounds may have to be constructed.

The Government having recently favoured the day-labour system, the employment of contractors has to a large extent been dispensed with, and the general works have been thus carried out. The work has been performed at least as cheaply as if contracted for, and no exorbitant claims by contractors have to be settled.

By the adoption of the designs and methods of cheap construction above described, a large saving per mile over the older method has resulted, and this without in any way increasing the cost of maintenance and working expenses. The Author is of opinion that if the railways in the interior recently constructed had been carried out according to the older methods, the cost per mile would have been between £1,500 and £2,000 greater.

The fencing can only be dispensed with when traffic can be conducted by daylight, and ballast should be left out only where the climate is a dry one and where the traffic is comparatively light. In a moister climate, and with frequent trains, ballast would no doubt be necessary if the road is to be kept in thorough repair.

The expenditure on land-resumption is generally a very trifling matter. The land is to a large extent still in the hands of the Crown, and where alienated the owners are for the most part willing to give it free of cost in order to obtain the advantage of railway communication. On the Parkes to Condobolin line, already mentioned, the total cost of land resumption has been covered by the sum of £40.

The cost of rolling stock depends on the amount of traffic, and may in one case be many times greater than in another. The Author has therefore left out of consideration the item of expenditure which would vary according as one train or many were run per day, and which has really little or no bearing on the question of construction. . . .

The Paper is accompanied by nine drawings, from which Plate 5 has been prepared.

(*Paper No. 3198.*)

"The Tocopilla Railway."

By Robert Stirling, M. Inst. C.E.

The Tocopilla Mountain Railway was built to open up the extensive nitrate-of-soda deposits of Toco, Chili, a continuation to the south of the famous nitrate fields of Tarapaca. It is of 3 feet 6 inches gauge, with exceptionally sharp curves, and the design was made with a view to employing the heaviest type of rolling stock possible, for the most economical handling of the traffic on the heavy gradients. Of all the railways on the west coast of South America which climb the coast range of the Andes, it is by far the boldest and most difficult, owing to the rugged nature of the mountains, which there rise almost out of the sea, and are cut only by a ravine too steep and crooked to be available for a railway.

Starting from the port of Tocopilla, the line rises with continuous gradients, varying between 1 in 24·4 and 1 in 66·7, to a height of 4,902 feet above sea-level at mile 34, and thence falls with a steady gradient of 1 in 66·7 to 3,631 feet, at mile 54. Here is the station of Toco on the level of the nitrate grounds, whence branches run to the different nitrate works.

The line, *Fig. 1*, is divided by the ruling gradients into four sections, and attention to this feature has aided greatly in economical working. The first section is from the port to Barriles at mile 17, with a practically uniform gradient of 1 in 25 (maximum 1 in 24·4), and almost continuous curves, many of them of only 181 feet radius. The second section, 9 miles to "Central" Station at mile 26, has gradients averaging 1 in 37, but easy curves of not less than 500 feet radius. The third section, of 28 miles, rises 8 miles to the summit, and falls 20 miles with a uniform gradient of 1 in 66·7 to Toco at mile 54, also with easy curves; and the fourth section from Toco to the five nitrate works already established, in all about 17 miles, has easy gradients and curves on the main line, but sharp curves and steep gradients on the sidings within the works.

The first section of 17 miles alone presents difficulties in construction or working, and is the only one that need be particularly described. Starting with a reverse just outside the station at Tocopilla, the line begins at once to climb the hillside parallel with the sea-shore to mile 4, where there is another reverse, at 796 feet above sea-level. Returning directly above this line for over a mile, it then begins winding on the sides of almost perpendicular hills, in and out of the side gulleys, high above the bed of the main ravine, with almost continuous rock-cuttings and curves, to mile 15. There it reaches the level of the main ravine, which has opened out to a valley, and continues in it for the remaining 2 miles with slightly easier gradients and curves.

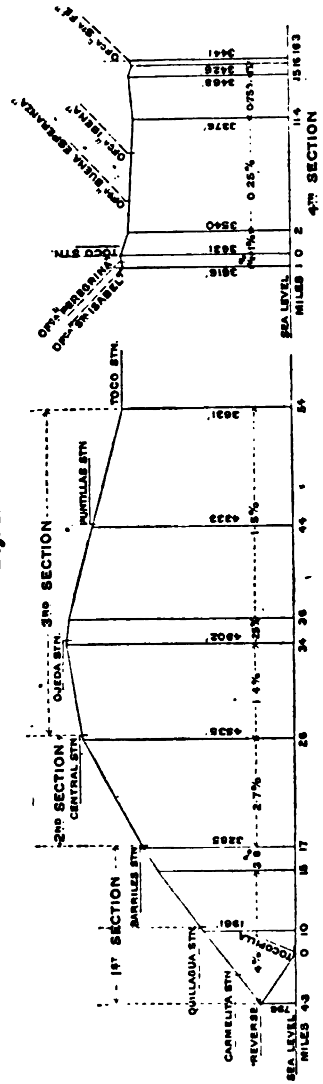


Fig. 1. Horizon'al scale, 1 inch = 16 miles. Vertical scale, 1 inch = 4,000 feet.

The curves on this section, and the proportion they bear to the total length of 17 miles, are approximately shown in Table I.

Several of the sharpest curves are through more than a semi-circle, and between very many of the curves there is only 24 feet of straight line. By adopting such sharp curves bridges were altogether avoided, and only one short tunnel was required; and the saving in cost was very considerable, as compared with minimum curves of even 250 feet radius. This would no doubt have been saved many times over in the working-expenses, for the sharp curves on this section add seriously to the cost of working the railway; but money was scarce, and the railway had to be

built within a certain sum or not at all; while in view of the heavy traffic which will have eventually to be carried when the district is fully opened up, it was not advisable to reduce the gauge.

The greatest care has to be taken to keep the curves in shape for the passage of the heavy locomotives and cars, and the side wear of the outside rails on the curves is excessive, as will be seen from *Fig. 4*. The line is laid with rails of only 40 lbs. per yard, but these are being replaced on the gradients by rails of 48 lbs. per yard.

The gauge on curves is ½ inch wide, and the rails are kept in gauge by tie-bars catching the flange of the rail, so as not to weaken the section by drilling, and by double spikes on the outside rail. Latterly also sole-plates have been used, under the outside

TABLE I.

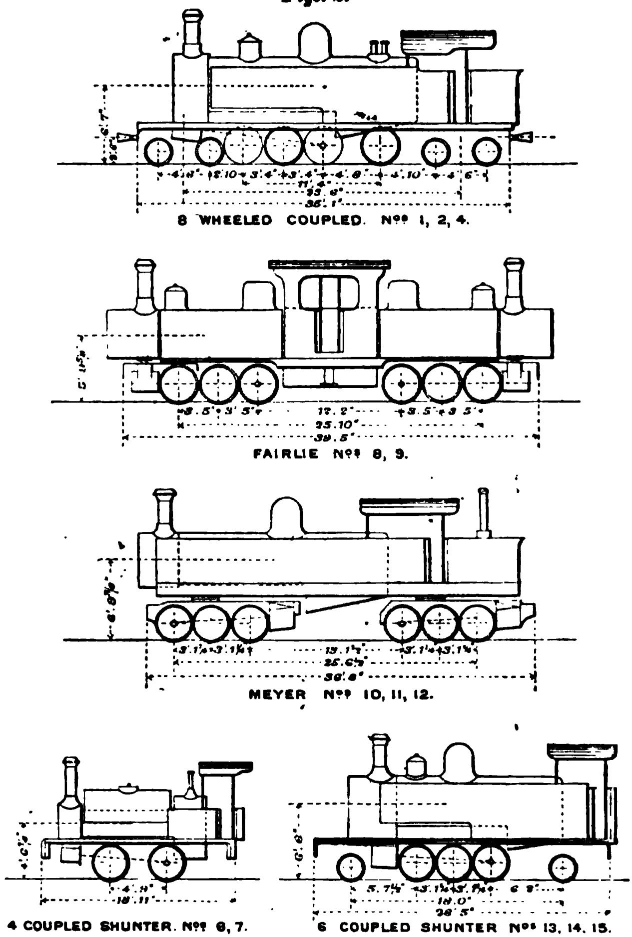
Radii of Curves.	Number of Curves	Total length.	Per Cent. of Total 17 Miles.
Feet.		Yards.	
181	37	4,128	13·8
Between 181 and 250	79	6,888	23·0
„ 250 „ 300	31	3,016	10·1
„ 300 „ 400	35	3,048	10·2
„ 400 „ 600	31	3,232	10·8
over 600	35	1,088	3·6
Total curves . . .	248	21,400	71·5
„ straight . . .	..	8,520	28·5
Total . . .	..	29,920 =17 miles	

rail, on every alternate sleeper. The sole-plates as originally supplied had to be slipped over the ends of the rails, and were found so inconvenient that they were almost discarded. However, by altering them slightly they have been used with good effect, as each takes four spikes well distributed in the sleeper. The spikes are of the ordinary pattern, $\frac{7}{16}$ inch square, and weighing 7 oz. each. The sleepers are of native Chilian woods, 7 feet by 8 inches by 4 inches, and in the rainless climate will last easily twenty years or more; except on the curves, where the frequent re-spiking reduces the life to about six years.

The superelevation of the outer rail on all the curves under 300 feet radius is fixed at 3½ inches, but on the short curves even this cannot be obtained, because, to suit some of the heavy single locomotives, the elevation has to be increased very gradually, and

not more than 1 inch in 24 feet. While it requires one man to ⅔ mile to keep this section in repair, the other sections only require one man to more than 2 miles, or, in other words, just as many men are needed to keep this 17 miles in repair as for the remaining 54 miles of line.

Figs. 2.



The different classes of locomotives in use are shown in Table II and *Figs. 2.*

The eight-coupled single locomotives were originally intended to do the work on all the sections of the line, but, although designed to be extremely flexible for engines of this class, they

TABLE II.

Class.	Weights. Total Weight.	Weights. Weight on Drivers.	Diameter of Wheels. Drivers.	Diameter of Wheels. Bogie.	Cylinders. Diameter and Stroke.	Boiler. Internal Diameter of Barrel.	Boiler. Heating Surface. Firebox.	Boiler. Heating Surface. Tubes.	Boiler. Heating Surface. Total.	Boiler. Tubes. External Diameter.	Boiler. Tubes. Length.	Boiler. Tubes. Number.	Boiler. Area of Grate.	Boiler. Pressure Lbs. per Square Inch.	Tank Capacity. Coal.	Tank Capacity. Water.	Train-Load on Gradient of 1 in 25 excluding Locomotive.
	Tons.	Tons.	Ft. Ins.	Ft. Ins.	Ins. Ins.	Ft. Ins.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Inches.	Ft. Ins.		Sq. Ft.		Tons.	Gals.	Tons.
8-coupled, Nos. 1, 2, 4.	51·75	34	3 2½	2 0½	2 17 × 21	4 3	93·15	881·65	974·8	1¾	11 2⅞	174	16	160	2	2,070	65
4-coupled, shunter, Nos. 6, 7.	16	16	2 10¾	..	2 10½ × 16	2 7	31·9	271·5	303·4	2	8 4½	64	5	140	0·37	350	20
Fairlie, Nos. 8, 9.	57	57	3 0	..	4 14 × 20	3 5½	38·4 38·4 76·8	573·8 573·8 1147·6	612·2 612·2 1224·4	1¾	10 8½	117 117 234	9·65 9·65 19·3	160	2	1,700	120
Meyer, Nos. 10, 11, 12.	53·5	53·5	2 10¾	..	4 14 × 18	4 4	104	1069	1173	1¾	11 3$\frac{1}{16}$	211	24·1	160	3	2,000	120
6-coupled, shunter, Nos. 13, 14, 15.	37	27	2 10¾	2 0½	2 14 × 18	3 9	62	574	636	1¾	9 11½	128	11·2	160	1·47	1,000	50

were found impracticable on the sharp curves, owing to too great rigidity causing excessive wear of tire-flanges. They are now used on the other sections where curves are easy, and there do excellent work.

"Fairlie" engines were then installed for use on the first section, but have been superseded by "Meyer" single-boiler engines. These were built in 1893, and are the first locomotives of this class built in England. They were suggested by the Author after studying the working of "Fairlie" engines on the "nitrate railways" of Tarapaca during 1887–89.

In designing these locomotives the problem was to improve on the "Fairlie," while keeping the maximum weight per axle to 9 tons. This admitted of an engine weighing 54 tons, and to make full use of this adhesive weight boiler and cylinders in proportion had to be provided, and a capacity of 2,000 gallons of water and 3 tons of coal. Table III shows the performance of these three classes on the first section, taken from actual working:—

TABLE III.

Class.	Total Weight.	Weight on Driving Wheels.	Net Weight of Train.	Lbs. of Coal per Pulling Mile.
	Tons.	Tons.	Tons.	
8 coupled single	$51\frac{3}{4}$	34	65	160
"Fairlie"	57	57	120	272
"Meyer"	54	54	120	210

The above results were obtained with patent fuel; but coal is cheaper and more convenient to use, and with it the advantage is still more in favour of the "Meyer" type, owing to the larger grate-area of which the design admits.

The six-coupled single engines were designed at the same time for the heavy shunting work between the mole and the station in Tocopilla, where the gradient is 1 in 25, and the 181-foot curves are numerous. They are also well adapted for the traffic between the nitrate works, for although the main line is free from sharp curves and gradients, yet in the sidings within the works both are found. The wheels and motion are interchangeable with the engines of the "Meyer" class.

The various classes of cars in use are shown in *Figs. 3* and Table IV. The original cars were wooden and weighed 5·6 tons to carry 12 tons, but by slight alterations they were made to carry 15 tons.

Next the steel cars were designed, with channel-section steel frames and corrugated-steel sides, weighing 5·5 tons, and carrying 20 tons. This gives the exceedingly good ratio of paying load to dead weight of 3·6 to 1. A number of high-sided cars are required to carry coal in bulk, but these weigh only a trifle more, 5·7 tons. A few tubular cars are being experimented with, but show no advantage in weight, and have nothing to recommend them. This low weight of cars has not been obtained at the expense of efficiency, for every part is of ample strength. The weights given include automatic vacuum-brake fittings, which add 537 lbs. to the weight of the car. Centre buffers are used with hooks, the slack being taken up by an eccentric gear. All have oil axle-boxes of the latest pattern.

The rolling stock is fitted throughout with automatic vacuum-

TABLE IV.

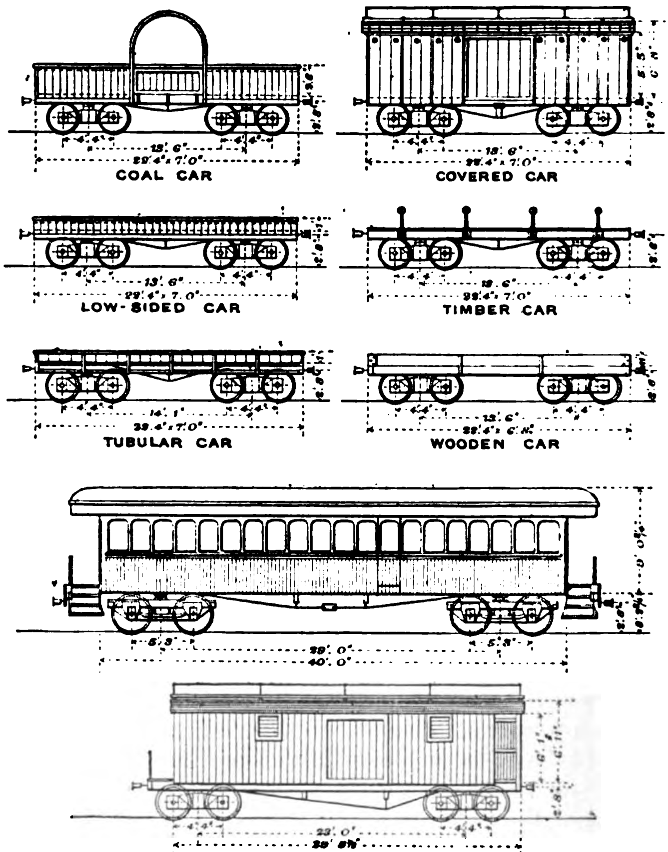
—	Weights.					Capacity.	Diameter of the Air-Brake Cylinder.
	Car Empty.	Net.		Total Weight with			
		Coal.	Nitrate.	Coal.	Nitrate.		
	English Tons.	English Tons.	English Tons.	English Tons.	English Tons.	Cubic Feet.	Inches.
Coal car . . .	5·70	12	20	17·70	25·70	390·83	18
Low-sided car .	5·50	5	20	10·50	25·50	156·33	18
Covered car . .	7·93	..	20	..	27·93	847·33	18
Timber car . .	6·16	..	20	..	26·16	..	18
Tubular car . .	5·74	5	20	10·74	25·74	156·33	18
Wooden car . .	5·60	5	15	10·60	20·60	134·69	15
Passenger car .	13·00	..	..	..	..	..	18
„ „ .	..	..	..	..	..	1248·00	18

brakes as well as hand-brakes and cast-iron brake-blocks; 18-inch cylinders are used on the steel cars, so as to get the requisite power without too fine adjustment of brake-blocks or dependence on a high vacuum. The gear is designed so that a vacuum of 12 inches is sufficient to control a train on the 1 in 25 gradients.

The water-supply has been a serious item in the cost of construction of the railway, and is in the working expenses. The country through which the line passes is absolutely devoid of fresh water, and all the water has to be distilled from the sea at the port or from the brackish water of the River Loa, 3 miles beyond Toco Station. The water of the Loa is almost equivalent to sea-water diluted ten times, and contains 245 grains of solid matter per gallon, 156 grains being sodium chloride. An attempt to use it in the locomotives during more than a year

showed that the train-load had to be reduced 25 per cent. on account of priming, and the corrosive action was such that the direct stays of the fire-box crowns, of iron $1\frac{1}{8}$ inch in diameter, were reduced in that time to $\frac{1}{2}$ inch in diameter next the copper plate. No system of purification was feasible, for although the lime could have been removed and the corrosive qualities could have been

Figs. 3.



counteracted, the sodium chloride would still have remained to cause priming, with the consequent reduction of train-load.

Two distilling plants were accordingly erected, one at the Port, and the other at the Loa, each with a capacity of 24,000 gallons per day. These are both sextuple-effect apparatus with six evaporators under an ultimate vacuum of 26 inches, and using salt water in

Lancashire boilers. The corrosive effects of distilled water are neutralized by adding lime in solution, and the proper proportion has been found by experience to be about 1 lb. of quicklime per 1,000 gallons of distilled water. From the port, part of the water is pumped through about 6 miles of 3-inch steel piping to the water-station at mile 10 at a height of 1,970 feet above sea-level, the pressure at the pumps being 900 lbs. per square inch.

From the Loa all the water produced is forced through 4-inch steel piping to the summit station of the railway, a distance of 23 miles, and 1,550 feet above the level of the pumps. Tanks of 6,000 gallons capacity at two intermediate stations are supplied from the pipe-line by valves $\frac{5}{16}$ inch and $\frac{3}{8}$ inch in diameter, regulated by hand, and at the summit there is a reservoir tank of 50,000 gallons capacity.

The railway is supplied with water by pipe-lines from either end, leaving a section from mile 10 to mile 34 to be supplied by car-tanks run down from the summit. The quantity used on this section is made comparatively small by arranging, as far as possible, for the down locomotives to fill their tanks at the summit to take them back, and by returning the double engines to the port from mile 17 with empty tanks. The original scheme was to supply the whole line and the port with river-water, but the impossibility of making it usable by any process of purification short of distillation caused this plan to be abandoned.

The cargo carried by the railway consists almost exclusively of coal, forage, and merchandise taken "up," and nitrate of soda brought "down." The "up" traffic is only about 25 per cent. of the total, and this distribution contributes very materially in reducing the cost of carriage, which under so many natural difficulties must necessarily be very high. Coal forms by far the larger portion of the "up" cargo, and high-sided coal-cars only load 12 tons and low-sided only 5 tons, while nitrate in bags is loaded 20 tons on a car. Notwithstanding this difference there is a good deal of empty "up" traffic, but all cars are fully loaded "down." The total traffic in 1898 was nearly 200,000 tons.

In working the traffic the advantage and economy of the steady gradients on each section is at once apparent. In starting from the port a "Meyer" or "Fairlie" locomotive is loaded regularly with a train of 115 tons to 125 tons, exclusive of the weight of the locomotive, and with this load is working steadily at 30 per cent. cut off, or to nearly its full power. With a dry rail a train of 135 tons can be taken up, but the lighter load is found to be more economical. The distance of 17 miles to Barriles is covered in

$2\frac{1}{2}$ hours, including 15 minutes for two stops to take water at miles 7 and 10. The "up" trains average eight to nine cars between loaded and empty, but may vary between six cars and fifteen cars to make up the load, depending on the cargo to be taken up and the number of empty cars required to bring down nitrate. The "down" journey is strictly timed to 2 hours for the 17 miles, which keeps the speed so that the train is always thoroughly under control on the sharp curves.

On the second section an eight-coupled single engine takes the load the double engine has brought up and one or two empty water-tanks, weighing about 9 tons each, covering the 9 miles in 1 hour.

For the third section the same engine takes two trains to the summit and down to Toco, 28 miles in $1\frac{3}{4}$ hour. On the "down" journey from Toco the load for these engines is twelve cars loaded with nitrate, making a train of 270 tons. This train is taken 20 miles on an up gradient of 1 in 66·7 and 8 miles on a falling gradient of the same amount to "Central" Station (mile 26) in $2\frac{1}{2}$ hours, including two stops for water. By arranging the traffic in this way a locomotive on an up grade is always working to its full capacity or maximum earning power. From "Central" down to the port the loads are arranged so that a train is never less than four cars, to help to brake the locomotive down, and as nearly as possible an equal train for each engine.

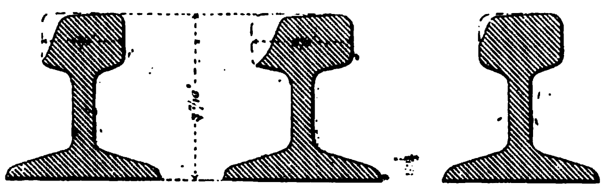
The real difficulties under which a railway of this class must be worked arise entirely from the sharp curves, for the heavy gradients, with the correspondingly heavy consumption of coal and water, and the absence of a natural water-supply, entailing the cost of distilling and pumping, can hardly be regarded as peculiar to any one railway. All that can be done is to pay especial attention to the consumption of coal and water by the locomotives, and to cheapen as much as possible the cost of distilling and pumping. These nevertheless form serious items of the cost of working, water representing 12 per cent. and coal 16 per cent. of the total working-costs of the railway. The division of the working-expenses of this railway is interesting for comparison with an ordinary railway.

		Per Cent.
Permanent way (maintenance and renewals of line, &c.)		15
Locomotive department, running expenses (wages, coal, &c.) .	39	
" " repairs to engines and cars	21	
	—	60
Traffic and telegraph (station and train wages, lighting, &c.) . .		12
General (management, offices, taxes, &c.)		13
		100

The curves are the cause of a very appreciable part of the heavy consumption of coal and water, for the resistance due to them is equivalent to an additional height of 440 feet, or about 8 per cent. of the total height to the summit of the line. The gradient on the long curves of 181 feet radius is reduced from 1 in 25 to 1 in 33·3. Recognized formulas call for rather more than this, but it is very clearly shown in working that at the low speeds this is ample compensation for the increased resistance to the train on the curve. When a train is climbing the gradients at a speed of 10 miles per hour, if the regulator valve of the locomotive be kept in the same position, the speed of the train slightly increases as soon as it comes on an almost straight part of the line, and the same happens in like degree when it gets on one of the long curves of 181 feet radius with the gradient reduced 1 per cent. But the real difficulties due to the sharp curves are the wear of rails and tire-flanges, thereby adding 50 per cent. to the cost of maintenance of permanent way and repairs to rolling stock, or, say, a total of 8·4 per cent. of the total working-expenses. The sections of worn rails and tires show that this may well be *Figs.* 4 and *5*. These were taken by plaster casts from worn rails and tires.

In *Figs. 4* No. 1 shows one of the original 40-lb. rails taken from

Figs. 4.



No. 1.—40 lbs. per yard. No. 2.—48 lbs. per yard. No. 3.—40 lbs. per yard.
Scale, ¼ inch = 1 inch.

the outside of a curve of 181 feet radius after the passage of about 71,706 wheels. When the wear has reached this stage the flanges of the wheels begin to cut the fish-plates, and the rails have to be renewed. Section No. 2 is of a 48-lb. rail, and with the wider head allows of double the amount of metal being worn away before the wheel flanges strike the fish-plates and the rail has to be renewed. Supposing the rails were of the same quality of steel, this would give double the life of the 40-lb. rails; but the 48-lb. rails proved to be much softer, and of the two lots of 48-lb. rails the harder gave a life of only 71,706 wheels for the loss of double the weight of metal, while the softer only gave 62,642 wheels' life

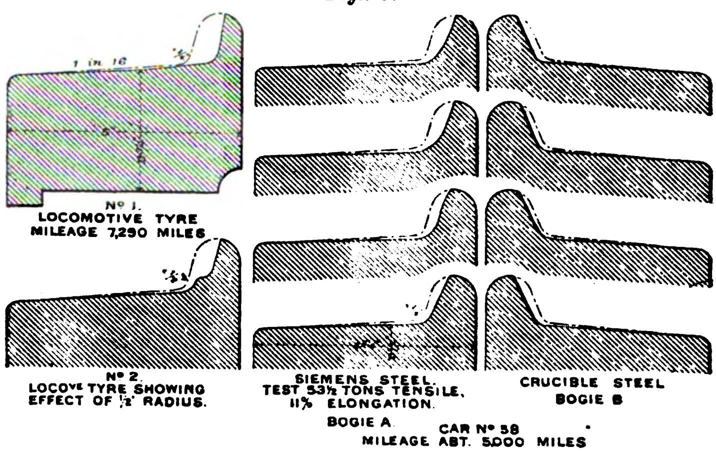
E 2

for the same wear. There was no appreciable loss in adhesion on the harder rails, although this has been advanced as a reason for using softer steel.

Section No. 3 is from one of the 40-lb. rails, originally laid on a curve of 302 feet radius, after 9 years' service, or, say, the passage of 550,000 wheels. This shows very clearly how little trouble there would have been had this been the minimum curve on the line.

In the wheel-tires, *Figs. 5*, the effect of the quality of the steel is even more marked. The section of locomotive-tire shows the template to which it has been found best to turn the tires, and the limit to which the flanges are allowed to wear before being

Figs. 5.



Scale, ¼ inch = 1 inch.

re-turned. The radius at the root of the flange has been gradually reduced from 1 inch to ¼ inch. With the larger radii the wheel, particularly on the bogies of engines and cars with light loads, was apt to climb the rail, and wear a groove, as shown in section No. 2, reducing the depth of the flange, and in aggravated cases causing derailment. To get a new flange ⅝ inch to ¾ inch must be turned off, so that a tire 2¾ inches thick can only be re-turned twice. It is found much more economical to run the flanges to this stage, as by far the greater part of the cost of re-turning consists, not in the loss of metal of the tire, nor in the actual work in the turning-lathe, but in the work entailed in taking the wheels from, and returning them to, the locomotives and cars, and

the withdrawal of these from the traffic during the operation, while the mileage is so short that very often no other part of the engine or car requires repairs. For each turning the mileage has varied on the same engine, "Fairlie" or "Meyer," between 500 miles and 17,000 miles, depending on the quality of the steel of which the tire was made. The former mileage was from Siemens steel of ordinary hard quality to suit English practice, say 45 tons tensile, and the latter from crucible steel of a quality which the makers themselves have not been able to repeat. The analysis did not show anything very special, nor did the steel appear particularly hard in the turning-lathe, but in service the result was as stated. The nearest approach to this, until lately, has been in a special Siemens steel giving a test of 53 tons tensile and 11 per cent. elongation, which showed an average of 7,000 miles per turning. Lately tires of crucible steel of American manufacture have given regularly 12,000 miles per turning.

Car-tires of this same American brand of steel, and of Siemens steel giving the above special test, were put under the same car, and after 5,000 miles gave the sections shown. This shows very clearly how much depends on the quality of the steel, and how much is to be expected, when a quality such as that giving 17,000 miles can be obtained with certainty.

The railway was originally designed for lighter rolling stock—4-coupled "Fairlie" locomotives of 36 tons weight and bogie-cars carrying 10 tons—and there is no doubt that, had these types been adopted, the difficulties of rail- and flange-wear on the curves would have been avoided. However, it has been clearly proved that, taking into consideration the working of the whole railway, it is now more economical to have the present heavy rolling stock, notwithstanding the excessive wear of rails and tyres involved by the curves of the first section.

"Fairlie" or "Meyer" engines of the above weight for the working of the first section would have taken two-thirds the present loads, and 6-coupled engines, taking three-quarters the load of the present 8-coupled class, would have taken their place on the other sections, and the cars would have carried half the load of the present steel cars. Thus, about 50 per cent. more locomotives would have been required, each costing little less than the present heavier engines, and double the number of cars, each costing at least 75 per cent. of the cost of the present cars, and almost certainly giving a greater proportion of dead weight. With a 50 per cent. increase in the number of trains run, wages of train-personnel would have increased in like proportion, and more than neutralized

the saving in permanent-way expenses due to less wear and tear of curves, while repairs to a greater number of locomotives and cars would have made the cost of maintenance of rolling stock as high as it now is for a less number, subjected to heavier flange wear. There would therefore have been an expenditure of 50 per cent. more capital in rolling stock, and no reduction whatever in working costs, but more probably an increase. This has been the gain so far due to the heavy rolling stock, and in the future the gain in reduced working-expenses will be clearly apparent.

By increasing the radius of the curves to a minimum of 300 feet the working-expenses would be at once reduced by the 8 per cent., which, as already stated, is the estimated extra working-cost due to the sharp curves, but this would entail an expenditure which would not be recouped in years by the economy obtained. Whereas, without extraordinary expenditure, by merely renewing the rails and tires as worn with a harder quality of steel, a reduction of 5 per cent. in the working expenses would be obtained in say 3 years, and the extraordinary expenditure on improving the curves can be undertaken as warranted by increased traffic, and will yield proportionately greater results.

It appears, therefore, after the experience gained on this railway, that a line with sharp curves can be equipped with relatively heavy rolling stock with economy in capital expenditure and in working-costs, and that, when an ultimate heavy traffic is expected for the railway, there is no question that this is the right policy. The curves can always be improved when the traffic warrants the expenditure, but light rolling stock, once adopted, must always interfere with economical working when the improved curves admit of heavier rolling stock, or, if replaced, will entail expenditure additional to that required for the improvement of the curves alone.

The line was designed by Mr. William Stirling, of Lima, Peru, and was opened for traffic in October, 1890.

The Paper is accompanied by three drawings, from which the Figures in the text have been prepared.

Discussion.

Sir Douglas Fox.

Sir DOUGLAS FOX, President, regretted that neither of the Authors was present that evening, Mr. Deane being in Australia, and Mr. Stirling in America; and therefore all that could be done was to pass them a vote of thanks, which would convey to them the appreciation by the Institution of the information communicated to it. He considered that the Papers were very practical essays on an important subject, and one needing to be frequently brought before the Institution. If English engineers were to hold their own in the world it was very important for them to study as far as possible economical railway construction. To his mind there was something refreshing about the Papers. The Institution nearly always had brought before it economical construction and break of gauge combined; but he was glad to see that the Authors showed how economy could be attained, without at the same time introducing what he thought was often a serious drawback, viz., break of gauge. Mr. Deane showed that without departing from the standard gauge of the country it had been possible to reduce greatly the cost of the railway by making certain detailed alterations. Not only was it proved that the gauge need not be broken in order to effect considerable economy, but both Papers pointed practically to the same methods for reduction of cost. The proper adjustment of the minimum radius of curves to the country traversed, the question of the ruling gradient, which was often neglected, and the concentration of the steep gradients as much as possible on certain sections of the railway, had been very carefully studied. An important point, which had been casually referred to in a discussion at the Institution recently, was the shortness of the tangents. Mr. Stirling mentioned that in some cases the length of the tangent was only 24 feet, which was very short. He had found in dealing with railways in difficult countries that nothing helped so much to get round sharp spurs of hills as reduction, as far as it could safely be made, of the length of the tangent. That was a matter about which English engineers and their foreign brethren often disagreed. Some foreign engineers would not even hear of a tangent of what English engineers considered a reasonable length; but it was clear that the introduction of any considerable length of tangent when dealing with sharp reverse curves very much did away with

Sir Douglas Fox. the effect of the curves themselves. Both the Authors had referred to the subject of ballast. In his experience he had found that, in dealing with moderate speeds—say 25 miles an hour, as, for instance, was the practice on the Rhodesian and other railways in South Africa—a very small quantity of ballast was often sufficient. Over considerable portions of some of the railways no ballast at all had been used at first, but it had been added afterwards as the traffic justified it and the call for increased speed necessitated it. Thus a very small average quantity of ballast had served at first, and it had been found that this did not produce any very serious increase in the cost of the maintenance. He observed in one of the Papers that cuttings were avoided as much as possible, and that appeared to have been copied from American practice. He did not quite understand why it was introduced into Australia. It was done in Canada and the United States on account of the heavy snowstorms, and there care was taken to lay out the line—not so as to balance cuttings and banks, as was done in this country—but without cuttings if possible, and to get over the ravines with trestles of timber, afterwards gradually filling in with earth. He did not quite understand how the economy was effected in Australia where heavy snowstorms were unheard of.

Mr. Robertson. Mr. F. E. Robertson said the Papers were certainly most practical and interesting, for, after all, the main object of engineering should be to afford the maximum of accommodation for the minimum of cost, and not necessarily to build monumental and consequently expensive structures. The problem of local communication seemed to have been well solved in Australia, because the cost of the lines, which appeared to be fully equal to the wants of the districts, was rather less than the average cost of the metre-gauge lines in India, although it would be seen from the rates given that the cost of earthwork on the Australian lines varied between four and eight times the Indian cost, labour, of course, being exceedingly dear in Australia. But it appeared that the rate given for the iron part of the permanent way was rather low for an average estimate. There would be about 100 tons of iron per mile in that permanent way which would give a rate of only £6 6*s.* per ton; and if that was really the price including the freight to site, it was extremely low when it was considered that the spikes, fishplates, and bolts were averaged with the rails. There was one item of extravagance he regretted to see, viz., the high platforms. Considering that the whole of the Continent could do without them, he thought local lines which required economical construction could very well do without them also. With regard

to the question of ballast, the rainfall had a great deal to do with that; the less the rainfall the better could ballast be dispensed with. The State Railways in Egypt were practically not ballasted at all, and yet between Cairo and Alexandria there was quite a respectable express service; so that it was possible to use unballasted lines for other than slow traffic. If the service was at all fast the dust was a great nuisance, and therefore a little ballast might be very desirable. He supposed that in Australia brick ballast would be too dear in places where no stone was to be had. With regard to the remark in Mr. Deane's Paper respecting the mode of carrying out the works, experience in India favoured task-work or petty contract, that was, letting items of the work to gangs, rather than using day labour pure and simple. It was certainly more economical, and gave a good deal less trouble. With respect to Mr. Stirling's Paper, for such heavy service the rails appeared to be somewhat light. Opinion in India favoured a 50-lb. rail for the metre gauge, with 8 tons as the axle-load. The statement in the Paper that the 48-lb. rail had given no better service than the 40-lb. rail gave rise to some reflection. There seemed to be an impression abroad that the rails obtained now, from differences in manufacture, were softer than they used to be; but even if that was the case, was the difference in date between the laying of the 40-lb. and the 48-lb. rails sufficient to account for the difference in wear, or was it possible that the 48-lb. rails were laid on the same centres as the 40-lb. rails, and consequently were a little tighter to gauge, as the tables were wider? That might possibly account for the wear up to the limit being as rapid in one case as in the other. He would like to ask the Author whether the curves were spirals, because with such very sharp curves every refinement in laying out seemed to be desirable; also whether check-rails were used, as there was no mention of them in the Paper. He would like to know, too, more about the coupler and how it had behaved on the very sharp curves on the line. From the brief description given it seemed to be a variety of what was known as the Norwegian coupler. That coupler in certain cases had given trouble on lines with less sharp curves and heavy gradients than the line in question. Mr. Robertson.

Mr. ELLIOTT COOPER thought the two Papers would be of even more value than they were, if they could be taken as representing in any degree what could be adopted as a general practice; but he need scarcely point out that the first Paper spoke of railways in a particular country, and special stress was laid on the fact of its having a very arid climate. He happened to be associated Mr. Cooper.

Mr. Cooper. with two countries, one of which—Cape Colony—might be described as having a somewhat similar character to New South Wales, whilst the other was an exceedingly humid country, quite the opposite of the first in climate. He was quite sure that methods adopted in the one would be altogether unsatisfactory if applied to the other. He would refer briefly to the various items of construction, to see how the very low expenditure set forth in the Table could be accounted for. In the first place, the railway in question was simply laid on the surface; and of course, in a country where there was very little rain, the question of ballast was really a matter of small consideration, because with a sandy soil or a perfectly dry soil, and no streams, or very little water, the line was quite as good without ballast, especially with steel sleepers, as a ballasted road in England. Steel sleepers, however, were not used on the New South Wales lines. The method of carrying out the earthwork was the method commonly adopted at the Cape also. It did not pay in those countries to use ordinary contractors' plant, which, in fact, was quite unknown. The embankments were made from side cutting, the natives simply shovelling up the material from the side and throwing it on to the track. Cuttings were made by casting out the material to the side. The banks and cuttings were made quite independently, but that could only be done where, as described in the Paper, both were shallow. That was a very general practice, and was much cheaper than any attempt at using tip-wagons or any other mode of carrying the earth from the excavation to the embankment. The land was of practically no value, and therefore the fact that side cuttings occupied a certain area of land did not entail any material addition to the cost of the railway; in that respect, therefore, it was a comparatively simple operation. The item which struck him as being the lowest—and it applied equally to all railways, whether light or heavy—was the permanent way, to which the previous speaker had referred. The freight to Australia must be very low if rails, a little over 100 tons of which were required per mile, were delivered at £6 per ton, including the fastenings and fish-plates. Culverts and bridges constituted also a very small item, evidently because there were practically no water-courses. The mode of crossing the waterways described in the Paper might be very suitable in a dry country, but in Jamaica, for instance, the bridge would hardly last more than 3 years or 4 years, so that it would be a very expensive method of dealing with works of any magnitude to build them of timber. Again, if such a structure were built at the Cape,

Mr. Cooper.

it would cost very nearly as much as if it were of steel, because in that country timber was exceedingly dear. It happened that in New South Wales timber was available and local conditions existed which made that form of construction suitable; and the members should not go away with the idea that a railway could be built, at the cost mentioned in the Paper, where such exceptional conditions did not exist. With regard to the practice of doing without fencing, the Author had referred to it as being applicable only in countries where the traffic was worked by daylight alone, which was of course quite an ordinary thing. For many years there had not been a yard of fencing in Cape Colony, except through cultivated lands, although there were 1,500 miles of railway working. The railways he had made there had never been fenced to begin with, but as the land became cultivated, the law of the country required the cultivated portions to be fenced, the owner of the land and the railway company each paying half the cost. If the railway was not fenced, gates were not required, and that expense was avoided. But it was not at all necessary to work a railway only in the daytime in order to avoid the provision of fencing. On the American lines a very large part of the route of the State express, which ran between New York and Buffalo, was entirely unfenced, even through the towns, where it ran across streets without any gates; and as that train ran at an average speed of 65 miles per hour, he thought it could scarcely be said that there was difficulty in working an unfenced railway unless it was worked in the daytime only. The lines at the Cape were worked day and night. With regard to stations, whether £213 per mile was exceptionally low or not depended entirely on their number; but the Condobolin station, he presumed, must have cost a large part of the total amount put down for stations on the line, because there were fairly good station-buildings, a goods-shed, an engine-shed, a turntable, a tank, and a 10-ton weigh-bridge, to say nothing of the cattle-yards and the fencing which all that necessitated, as well as the sidings. So that even with the low cost of permanent way, that station must have cost a substantial amount. The only other point he specially wished to refer to was the American system that had evidently been adopted in dealing with the sleepers. In America, where timber was exceedingly cheap, and the sleepers were simply got from the surrounding country and laid in the road, they were spaced in some cases not more than 18 inches apart. That was anything but economical from the point of view of maintenance, especially when

Mr. Cooper. it was borne in mind that maintenance ought properly to cover renewals. If the number of sleepers was doubled, and those sleepers only lasted a few years, this mode of construction was manifestly a somewhat extravagant one, as he knew from personal experience in another country. In the second Paper, stress was laid on the economy of sharp curves. A 5-chain curve was really a very reasonable curve, and one that could be worked without any serious inconvenience or danger. He had often run over such curves at a speed of 35 miles per hour. At the present time there were a large number of excellent locomotives running round 5-chain curves on the Cape lines, locomotives having eight wheels coupled, weighing, with the tender, something like 90 tons, and having about 9 tons on an axle. He had just had four of those engines built, and they were doing very satisfactory work. There were stretches of 10 miles or 15 miles of line, consisting largely of 5-chain curves with short lengths of straight line between them, and there was no difficulty at all in working those sections. The curves were combined with inclines of 1 in 40, and the engines could take a load of 200 tons up such curved inclines, so that he did not think special locomotives were really required to deal with curves, provided they were not of shorter radius than 5 chains. With regard to the diagrams showing the wearing of the rail, he knew of a case in which that had occurred, and to a large extent it had been caused by the rails being laid vertically, instead of with a cant, so that the flange of the wheel had been always wearing against the side, instead of the surface of the cone being perpendicular to the axis of the rail. He thought that might be in some degree the cause of the curious form in which the rails had worn. The question of economy in any case of railway construction must necessarily be largely governed by the particular circumstances of that case; for what was an economical railway in one place might be an inefficient and uneconomical railway in another. The Papers were valuable as giving an idea of what might be done where the circumstances were undoubtedly very favourable to economy.

Prof. Warren. Professor W. H. Warren remarked that Mr. Deane had stated in a clear and concise manner the practice which had been found generally most suitable for New South Wales, where the conditions were naturally different from those existing in a settled country. From his knowledge of the United States, the conditions in New South Wales appeared to be very similar to those in America, especially in the Western States, and pro-

Prof. Warren.

bably they were similar to those which existed in South Africa. That might be an interesting matter in the future when the railways of the Transvaal were developed by British engineers. In a country which was only partially settled by a small and scattered population, it was necessary to construct a railway economically, otherwise there could be no railway at all. Consequently, every means had to be adopted to reduce the cost of construction to a minimum, consistently, of course, with economical working. He thought the tendency in New South Wales was to avoid earthwork, as far as possible, in such railways as Mr. Deane had described, on the ground of its expense, the idea being to keep the line at the surface. With regard to the various sections showing the permanent way, perhaps the most interesting was that which showed an unballasted road; and although such a road would not be suitable where the rainfall was at all similar to the rainfall of this country, yet in the dry districts of New South Wales it had been found advantageous, or, at any rate, possible to use it, just as it had been in the Western States of America. The construction of such a road was not as easy as would appear at first sight. Great attention had to be given to drainage, water not being allowed to rest upon the surface at all. It would be noticed that the road was considerably arched in the centre and that it sloped down on either side to the level of the bottom point of the sleeper. That was an important point, because it meant that between each pair of sleepers there was a clear way for the water. If that was attended to, it was possible to make such a road work very well with the small traffic carried and the low speeds used on such pioneer railways. With regard to rails, a flat-bottomed rail was universally adopted in Australia because of the use of sleepers of ironbark or other hardwood timber. The hardwood timbers of Australia were very heavy and durable, the average life in New South Wales of ordinary red-gum sleepers being 25 years; and ironbark sleepers would last longer, though ironbark was a valuable timber, and rather too good for sleepers. That was a much longer life than could be obtained with pine timbers even after creosoting them on most approved plans. With a heavy sleeper, therefore, a flat-bottomed rail, and ordinary ballast, a good stable permanent way was obtained. He was speaking entirely from memory and had in mind the results of calculations made in the past, but he thought if the weights per mile of the rails and sleepers in the permanent way of the New South Wales railways were

Prof. Warren. taken out and compared with the weights of the permanent way of other railways it would be found that the permanent way of the New South Wales railways weighed more, so that they were at least a little more stable than ordinary railways carrying the same weight of rails, simply in consequence of the extra weight of the sleepers. The design of structures, also, was governed by the materials at hand. The Australian timbers he had referred to were also very valuable for beam-bridges or truss-bridges. Ironbark was almost universally adopted in New South Wales for the construction of timber trusses, or the various spans of beam-bridges. In the diagram, Fig. 4, Plate 5, for instance, there was an opening of about 14 feet, and in a 14-foot opening of a beam-bridge it was possible to do very well with three ironbark beams, 12 inches by 12 inches, spaced so that the load would be equally divided over each beam. That was the most convenient and marketable size which the growth of the trees allowed to be cut; and it was hardly possible to get timber deeper than 12 inches in large quantities, a fact which in itself had caused the methods of construction to differ widely from those adopted in America for timber trestle beam-bridges. There two or three timbers were placed in a group under each rail, each beam being about 4 inches wide and 16 inches or 18 inches deep. That method had been adopted with pine timber simply because it could be most conveniently obtained in those proportions. The only danger was that the beam might be made too deep, and might fail by longitudinal shearing along the neutral axis towards the end. That was not likely to occur with Australian timbers, because they were very strong in horizontal shear, and, in fact, strong altogether. Ironbark was at least one-third stronger than the strongest oak, the modulus of rupture being about 13,000 lbs. to the square inch in beams 12 inches by 12 inches. It was, therefore, quite possible to design a timber bridge that would carry the heaviest engines on the New South Wales Railway; or, in the case of the light railways described in Mr. Deane's Paper, where the weight on an axle would not exceed 12 tons, two ironbark beams, 12 inches by 12 inches, would probably be used. In designing a bridge for a span of say 20 feet, 12-inch by 12-inch beams could not be very well put side by side, as the weight would not be equally distributed over them. In that case one beam was placed under the other, and the two were united by wedges and bolts. Various attempts had been made to construct a compound beam which would be as stiff as a simple one of like depth, and it had been found

that by placing the wedges diagonally, and slicing pieces with a saw out of the bottom and top of the upper and lower beams respectively, wedges could be put in, the beams could be bolted together, and a compound beam was made which had about 90 per cent. of the strength of the simple beam but was not quite as stiff. For longer spans, the diagram showed a 60-foot truss-bridge with timber top and bottom chords and, apparently, vertical steel bolts, which could be screwed up to adjust the timbers. The timber tended to shrink, and when it shrank it was necessary to bring the wood together again. By keeping the angle of the diagonal members the same, there was no difficulty in adjusting shrinkage by merely screwing up the bolts. A still better plan appeared to be to place the steel bolts diagonally, and to arrange the timber compression-members vertically. If models made on the two styles were examined, it would be seen at once that there was greater stiffness in the bridge made with vertical timbers and with diagonal steel or iron bolts. That form of bridge had given great satisfaction, not merely for railways but also for roads. It would be noticed that the bridges had what was called the American deck, consisting of timbers spaced 6 inches apart, on which the rails were laid. That formed a very good way of constructing permanent way over bridges. Mr. Deane said that the sleepers on the unballasted road were spaced about 2 feet 2 inches between centres; and, of course, by spacing the sleepers so closely a good deal of the difficulty caused by not having sufficient ballast was got over. Prof. Warren.

Mr. HORACE BELL said there was only one point he would like to accentuate in the discussion, and that was the question of ballast, which weighed on the minds of many members in connection with the construction of light railways. In the case of a great many lines a very good shift could always be made by using ordinary river-sand, which could generally be obtained very cheaply; or, in many cases, the soil itself might be found to be sufficiently sandy to stand a heavy traffic without any addition whatever, as his own experience had shown him. The drainage of such sandy soil was comparatively immaterial. When the sand from rivers and streams was used, a sufficient thickness could be obtained very often for but little more than the mere cost of digging, and it required no special cross section in the embankment. The whole tenour of Mr. Deane's Paper would lead the members to see that the construction of a cheap railway was largely due to exceptional circumstances, and certainly in the case of the particular line referred to it was due very largely to the Mr. Bell.

Mr. Bell. existence of ironbark trees in the vicinity. Such wood as that was invaluable to the engineer for constructing cheap railways. But it should be remembered that the construction of timber bridges was not a question of the mere materials of the bridge; it was more a question of the working up, or the joints in the timber, which were the first places to fail. However cheap timber might be, or however durable it might be, the joints would give, and from that point of view the class of line that Mr. Deane had described, although cheap, was more or less a temporary line, and that view, he thought, would be accepted by the members.

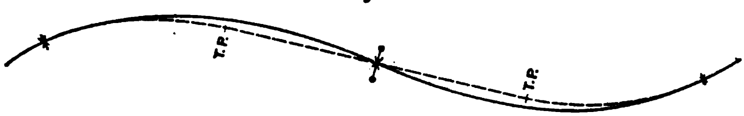
Mr. Robertson. Mr. F. E. Robertson thought that, apropos of what Mr. Bell had said about the use of sand for ballast, it might interest the members to know that on the East Indian Railway there was a section of about 25 miles of the old loop line constructed before the Mutiny, which was laid with sand-ballast and pot sleepers, and a light boxing of brick to keep down the dust. He did not know how many pots had been changed since the line was made, but during the time he had been chief engineer that section had kept in excellent order. It was fairly light in maintenance, and breakage of the pots was exceptional. It would thus be seen that sand in certain cases made excellent ballast.

Mr. Rigby. Mr. J. Rigby remarked that the form of permanent way referred to in Mr. Deane's Paper appeared to have been adopted because the ballast was of earth. The Author alluded to cutting it away from the end of the sleeper to prevent the traffic splashing it up on to the working parts of the locomotive. He had had a good deal of experience in a country where there was practically nothing for ballast but black vegetable earth, and he had found that on the whole it formed a very good ballast. It was necessary in that case to keep the boxing somewhat in the style of Fig. 9, Plate 5. That was in the Argentine Republic, and roads there were ballasted almost to the shoulder of the rail. They were kept a little low between the rails to prevent the flange catching up the mud. In that way a surface was formed from which the rain ran off, and water did not lodge under the sleeper. Occasionally, when the road had been freshly packed and heavy rains came on, the water soaked through and caused a little trouble by lodging under the sleeper, but, on the whole, earth formed a very good ballast. One thing struck him with regard to the peculiar manner of cutting away the ballast, viz., that whilst on the American lines it was carried out on comparatively straight roads, on the New South Wales lines there were very sharp curves; and it seemed to him that such an unballasted road would be very difficult to keep in

line. On railways in Brazil, where there were equally sharp curves, he had seen the road shifted over 10 inches under a passing train, although there had been a shoulder of ballast of decomposed granite outside the sleeper. In New South Wales, where there was no ballast at all, and the road was simply held in position by friction under the sleeper, he would have thought that heavy engines travelling at even a moderate speed would throw the road considerably out of line. He thought Mr. Deane might give some information on that point. Mr. Rigby.

Mr. DEANE, in reply to the Discussion, remarked, with reference to the President's observations on the insertion of tangents of sufficient length between reversed curves in hilly country, that it was now the general practice in New South Wales to have all curves laid out in the first instance with straights at least 4 chains long between them. This admitted of the use of transition curves about 4 chains in length, or twice the half length to each curve, *Fig. 1.* All curves of a radius of 20 chains and under, whether single or reversed, had transition curves at their ends. These Mr. Deane.

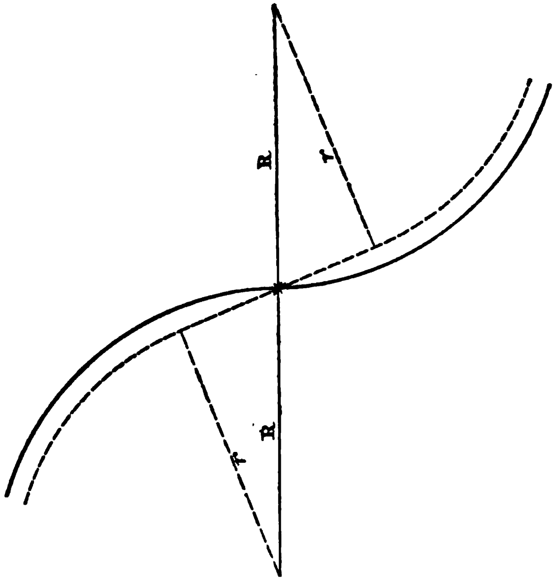
Fig. 1.



were set out on the cubic-parabola principle by means of Tables applicable to each particular case. The length of straight line left between the ends of reversed curves after absorption by the transition curve might be very short, even nil, but no difficulty was experienced by the rolling stock, as the change from the radius of the middle part of one curve to one of infinite radius, and then over the transitional part of the reversed curve to the other proper curve, was very gradual. The radius of the sharpest curves now laid out for new lines was 10 chains. There was much less difficulty in finding room for transition curves, even in rough country, than would at first sight be supposed. If R were the radius of two reversed curves between which it was desired to place a tangent of 4 chains length, the curves must be set in the centre, *Fig. 2*, the new radius r being given by $r^2 = R^2 - 2^2$ and if $R = 10$ chains, then $r = 9 \cdot 795$ nearly, or only $20 \cdot 2$ links shorter than the original curve. If 10 chains was the limiting radius, as in New South Wales, then all that was necessary was to use a slightly longer radius for the curves of the preliminary survey, calculated from the same equation, $R^2 = r^2 + 2^2$,

Mr. Deane. and R = 10·198, where *r* was 10, the difference thus being less than 20 links. Cuttings were avoided where possible because the drainage was so much more effective on banks and the cost of maintenance was less. The water falling on an embankment ran off at once; the weathering on the slopes of cuttings caused an accumulation in the water-tables which reduced the drainage of the formation, and the latter tended to become sodden under the sleepers if the water-tables were not kept very clean, which of course involved expense. This was the only reason for avoiding cuttings. The American method of erecting timber trestles over

Fig. 2.



ravines, with a view to economise time and earthworks in the first instance, would not pay in Australia, where the hard woods used were so much more costly than pine in America. As had been remarked by Mr. Robertson, the prices of rails and fastenings, when the estimates for the Parkes-Condobolin Railway had been made, had certainly been low. The average price of steel rails and fastenings delivered in Sydney, up to 18 months ago, had been about £5 per ton. The last rails and fastenings ordered would cost about £7 10*s.* 0*d.* per ton delivered in Sydney. The steamer-freight for rails from England had been as low as 5*s.* per ton, but the price paid for many years had been 7*s.* 9*d.* per ton. The

railway carriage charged from the stores to the works was at the rate of 1*d.* per ton per mile. The weights of 60-lb. rails (in lengths of 30 feet) and of fastenings per mile were the following:— Mr. Deane.

	Tons.	Cwt.	Qrs.	Lbs.
Rails	94	5	2	24
Fish-plates	6	18	1	14
Fish-bolts and nuts	1	0	2	27
Spikes	3	6	2	13

By brick ballast Mr. Robertson presumably meant burnt ballast. This would be too expensive, as suitable material was rare in the interior, and fuel was difficult to obtain. With regard to piece-work, this principle was frequently made use of in excavating, where there were too many stumps in the ground to use the plough and scoop, and where it was therefore necessary to use pick, shovel and barrow. Small contracts for taking out cuttings, for bridge-tops, etc., were let; but, generally speaking, day-work had been found to be quite satisfactory in its results, and it could of course easily be seen that, for plough- and scoop-work, piecework would be of no advantage; all that was required was an efficient ganger to see that men and horses were kept steadily at their work. The cost of waterways was naturally low where rainfall was small; at the same time he thought the economy was due quite as much to design as to the small amount of waterways required. The rainfall in the interior of Australia, although generally sparse, was liable to great fluctuation. It occasionally happened that a district might have as much rain in 1 month as usually fell in a year; and 5 inches or 6 inches in 24 hours was by no means an uncommon occurrence over a particular patch of country. It did not appear desirable, however, to provide for very exceptional conditions which occurred at intervals of perhaps 20 years or 30 years, because if a low bank were washed away the damage was quickly and cheaply repaired.

With regard to the question of dispensing with fencing, it was generally considered that when travelling by night was necessary the line should be fenced, as sheep and cattle would camp on the formation at night. Trains did run after dark, however, on portions of the unfenced lines, especially in winter when the days were shorter; and then safety was secured partly by the adoption of a low speed and partly by an efficient look-out, rendered possible by a powerful headlight on the engine. With regard to settlement bringing with it the necessity for fencing, it was to be noted that there was considerably less risk in running at night through cultivated land with farm-crops and orchards, where

Mr. Deane. there was no stock likely to stray on to the line, than through pastoral country. A little calculation would show the economy of close sleepering, and the saving in first cost compared with ballast. The new lines in New South Wales had about 580 sleepers per mile more than the previous design of permanent way. Taking the cost of these at 3*s.* each, the extra expenditure per mile was £87, which would be far less than that of ballast under most circumstances. As the sleepers lasted between 20 years and 25 years before they required renewing, it was clear that the annual cost of renewing the extra quantity was small. Guided by the results of his own observation, he was strongly of opinion that it paid to put in the extra sleepers even where ballast was used as well; the road obtained a better support, it was also less liable to subsidence and to lateral shifting, and consequently it was better and more cheaply maintained. The weight of the permanent way in New South Wales was, as Professor Warren thought, greater than that of most other countries, and the lines were therefore somewhat more stable. This was due to the high specific gravity of ironbark and other timber used. A cubic foot of ironbark weighed 70 lbs., and the permanent way of the unballasted lines with the 60-lb. rails weighed 343 lbs. per yard. In reply to Mr. Horace Bell, he did not understand how the class of line advocated could be called "temporary." If the traffic remained constant the line would require no improvement, and it was not easy to see why the use of a material such as ironbark, which had lasted in bridge structures at least 25 years, should earn for the line the character of "temporary." There were many examples of timber railway bridges of different designs in New South Wales, which had preserved their form in spite of age, and which had had to be renewed after a period such as that mentioned—not so much on account of deterioration, as because they had had to make way, like many of the old cast-iron and wrought-iron girder bridges in England, for a design more fitted to carry the heavier rolling-stock.

With regard to possible shifting of the roads on sharp curves, under passing trains, to which Mr. Rigby had referred, there were curves of 10 chains radius on portions of the unballasted lines already open for traffic, but with the limited speed adopted no damage seemed to be done. It must be remembered, as mentioned above, that the weight of the permanent way was very considerable, and must resist distortion. Further, the outer rail on all curves was of course elevated to suit the radius and a speed of 20 miles per hour, and the pressure on the earthwork when the

speed was 20 miles per hour or under would be normal to the inside of the curve. Mr. Deane.

Mr. Stirling, in reply to the Discussion, observed that the short tangent between many of the sharp curves, viz., 24 feet, had been fixed as the shortest practicable one for the eight-coupled class of locomotives. This only allowed for one bogie and the driving-wheels being on the straight line, while the other bogie was on a curve, yet the engines went smoothly from one curve to the other. It would be noted, however, that the speed did not exceed 15 miles per hour. Moreover, the full curvature was not given at the entrance to the curve, but was increased gradually in the length of the first rail (24 feet) at each end of the curve. Mr. Stirling.

It had been frequently found in revising the curves that the tangent was not more than 12 feet, but in such cases the eight-coupled locomotives were felt to lurch, although the "Meyer" and "Fairlie" engines still passed smoothly. On account of the almost entire absence of rain, the ballasting was a comparatively simple matter. On the first section, ballast of excellent quality was easily obtained from the hill-sides and water-courses, and this was the only section where rain ever fell. The other sections were ballasted with the dry baked salty mud of which the ground was composed. This generally contained a good percentage of sand and packed firmly, but in some parts it had no sand, and broke into a powder so fine that it was blown from under the sleepers by the movement of air caused by passing trains. In these cases sandy soil had to be brought from the nearest watercourse.

Referring to Mr. Robertson's question why the 48-lb. rails gave no better service than the 40-lb. rails, it would be noted that quality (*b*) of the 48-lb. rail gave really poorer service. The 40-lb. rails had been manufactured in Belgium, of a much harder quality than was produced by English makers; but although they had given so much better service there had been at first quite a number of broken rails. This had been chiefly, if not wholly, due to faulty manufacture, but the danger of a broken rail on the edge of a precipice was too great, and precluded the ordering of more rails of this make. The greater part of the line was laid with these rails, and except on the first section, where, owing to the sharp curves and heavy gradients, the service was exceptionally severe, there had been very few broken rails. English rails of ordinary quality, weighing 48-lbs. (*b*), had been obtained, and for double the loss of metal had given actually a poorer service than the 40-lb. rail.

Mr. Stirling. An attempt had been made to get a harder rail from English makers, and quality (*a*) was the result, but this again for double the loss of metal had given no better service than the Belgian 40-lb. rail. In the meantime the Author had been making inquiries, and had found that in the United States some of the leading railways had been specifying for harder rails, giving almost exactly the same analysis as the Belgian rails. The following Table gave the analyses of the different rails referred to:—

—	No. 1. Belgian.	No. 2 (*a*). English.	No. 2 (*b*). English.	American Specification.
Carbon	0·3495	0·60	0·49	0·45 to 0·50
Silicon	0·109	0·052	0·052	0·15 to 0·20
Sulphur	0·045	0·055	0·054	0·069 maximum
Phosphorus	0·062	0·045	0·060	0·06 ,,
Manganese	0·662	1·09	1·06	1·05 to 1·25

This had confirmed him in his opinion that the harder rails, if properly manufactured, could be relied on, especially as with the low speeds and more elastic road-bed obtained by flanged rails laid directly on wooden sleepers, the jars or blows on the rails were much less severe than on English railways. Unfortunately, for the small quantity required, the special section could not be obtained in America, but a comparatively hard rail giving an analysis approximating to that of the 40-lb. rail and of satisfactory manufacture had been obtained from the same Belgian makers. These rails were being laid on the curves at the end of 1898, when he had left Tocopilla, but he had no advice of the results obtained. At present there was great complaint in America that makers, in the present press to turn out steel, were producing rails of a softer quality, which did not give nearly as good results as the harder rails formerly obtained. The rails had all been laid to 3 feet 6½ inches gauge on the curves, and the 48-lb. rails had had to be brought in to this gauge when half worn, so that the conditions for both classes of rails had been identical. The curves were segments of circles, one rail only at each end being opened out gradually. No further modification had been possible on the sharper curves without incurring the extra cost which would have been equivalent to a curve of greater radius. No check-rails were used because of the extra friction they would have caused. Turton central buffers and hooks were fitted on the original cars, but on all new stock a simpler buffer with one spring on the draw-bar had been adopted. The slack of the hook was taken up by a simple eccentric as in the

Turton arrangement, but without the extra spring. The jaw of the buffer had to be wide enough to prevent the hook becoming jammed on the sharpest curve. No trouble whatever had been experienced with these buffers and hooks on the curves; a case of uncoupling was of very rare occurrence, and could almost always be traced to too great difference between the heights of the cars. No ring was used over the hook. He was aware that considerable trouble had been experienced on other railways with the hook-couplings, but it had never been quite clear to him whether this had been due to the want of the eccentric to take up the slack, or to want of care in keeping the heights of the buffers to standard. The trouble on one railway had evidently been due to the four-wheeled wagons in use, which naturally would give more vertical motion to the buffers on an uneven track than would be the case with bogie cars. Mr. Stirling.

In reply to Mr. Elliott Cooper, the radius of the curves was less than 3 chains (181 feet). Rail section No. 3 (*Figs.* 4) showed that the wear of the rails on a curve approximating to 5 chains (302 feet) was not excessive. All the rails were laid with a cant, each sleeper being channelled to a template. The form to which the rails had worn was such as would be expected from the flange of the tire being thickest at the root, and not so deep as the head of the rail. Rails worn to exactly similar form, though of course after much longer service, might be seen on curves on some of the main lines in the United States to-day. There was no doubt that economy in railway construction must be very largely governed by circumstances, but English engineers had always been too prone to base their specifications on conditions ruling on English railways, and to neglect too much local conditions and requirements. Had the specifications for the first railways in New South Wales, described by Mr. Deane, been adapted to the circumstances, as was the case with railways being constructed in America at the same time, large territories would have been developed years ago, and the colony would probably now have double the mileage. The astonishingly rapid development of the Western States of America had been entirely due to the rapid extension of economically constructed railways, which had been improved as the increasing traffic warranted.

Correspondence.

Mr. Amor. Mr. J. V. W. AMOR submitted the following comparative figures to show how insignificant was the advantage gained by adopting a gauge narrower than 4 feet 8½ inches:—

The Mexican Railway (Mexico to Veracruz).	Tocopilla Railway.
Gauge, 4 feet 8½ inches . . .	3 feet 6 inches.
Maximum gradient, about 1 in 22	1 in 24·4.
Radius of curves, 250 feet . .	181 feet.
Fairlie engines, weighing 62 tons in running order	Meyer engines, weighing 53·5 tons in running order.

There were one or two curves on the Mexican Railway of even less radius than 250 feet, and the gradients were not compensated on the curves. That railway rose from sea-level to an elevation of over 7,500 feet by a continuous series of such curves and gradients. In recent years Fairlie engines had been increased in size and power to about 90 tons, but for many years after the opening of the line in 1872 the 60-ton engines had been ample for all requirements.

Mr. Burge. Mr. C. O. BURGE, as principal assistant to the Engineer-in-chief in the construction of the New South Wales railways, which included the light lines referred to in the first Paper, wished to add his testimony as to the suitability of the method described to the objects in view. He would especially point out that in New South Wales—and the same thing applied more or less to all the Australian colonies—narrow-gauge light branches which had been proposed from time to time, and had been favoured in some of them, would have failed to meet the requirements which had been satisfied by the lines referred to in Mr. Deane's Paper, not only on account of break of gauge, but for other reasons. The evils of break of gauge might be broadly summarized as:—(1) Transhipment and demurrage caused thereby; (2) the closing of the branch as an asylum for old rolling-stock; (3) inability to draw upon the general system for extra rolling-stock to suit occasional excess of traffic, and the consequent necessity of providing otherwise useless reserves; (4) isolation as regards repairs to rolling-stock. These, bad as they undoubtedly were, might possibly be compensated, to some extent, in the narrow-gauge line, (*a*) by sufficiently-decreased capital cost; and (*b*) by decreased ordinary working-

expenses, apart from those specially due to the break of gauge and enumerated above. As to (*a*), Mr. Deane's Paper had shown to what low figure the cost of standard-gauge construction could be reduced, and it should be remembered that quite 20 per cent. of that cost was unaffected by gauge; and as to (*b*), the important effect of the specific gravity of the average of the paying load to be hauled had to be considered. The advocates of the narrower systems showed, truly enough, that under a certain condition, which was seldom realised, the ratios of dead to live load were entirely in their favour. That condition was, that the trucks were always or chiefly called upon to carry the maximum weight of which they were capable, in which case, obviously, the smaller stock had a great advantage. Now investigation of the character of the loading on the New South Wales country branch lines, taken from official returns, showed that hay, straw, wool, hides and live stock, all occupying wagon-space of between 300 cubic feet and 400 cubic feet per ton, formed nearly two-thirds of the up-loading; and as commodities occupying about 93 cubic feet per ton filled up the maximum space available with the maximum weight on the standard-gauge wagon of the latest type, it was evident that there was a large unavoidable waste of weight-carrying capacity for the greater part of the loading. The narrow-gauge stock, in consequence of the necessarily lower centre of gravity of the loading, would of course be much worse conditioned in this respect. A comparison of the standard-gauge working with that of a 2-foot gauge had been made in detail under the conditions named above, taking into consideration also the back loading, which was small; and the results showed that, for a given amount of traffic, the standard-gauge train-mileage would have to be more than trebled on the narrow-gauge line. The running-expenses of the latter certainly could not be so much less as to balance this. Intermediate gauges would of course give less excess in train-mileage, but the saving in capital cost (*a*) would also be less. Hence, if a narrower gauge had been adopted, in addition to the expense and inconvenience of the break of gauge, which were so difficult to estimate, large extra running-expenses and greater subsequent cost would have been entailed if increase of traffic in the future had required more capacious lines. The question of the character of the loading was not sufficiently considered when the gauge controversy was entered upon. Mr. Burge.

The first civilized state of new countries was, as a rule, pastoral

Mr. Burge. or agricultural, followed sometimes to some extent by manufacturing industries, the latter bringing large populations requiring speed and large capacity in railway accommodation. As shown above, the standard gauge was more generally suited for the first stage, and it had been proved by European and American experience, and indeed was universally admitted, that narrow gauges were insufficient for heavy and fast traffic. The conclusion was, therefore, that, in respect to gauge, the New South Wales Government had done wisely in carrying out the policy indicated in Mr. Deane's Paper in this particular.

Mr. Money. Mr. R. J. Money observed that since many people held an erroneous idea regarding the definition of a light railway, the fact that it was not necessarily one of narrow gauge deserved to be emphasized. This fact had been appreciated by the Italian Government Commission, which had sat as long ago as 1879, to consider the question of economical railways. It had divided them into five classes, three of standard gauge and two of narrow gauge. The following Table showed the chief particulars of each class :—

—	Trunk Lines of Standard Gauge.	Economical Railways.				
		Standard Gauge.			Narrow Gauge.	
		Class.			Class.	
		1	2	3	4	5
	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.		Feet. Ins.
Gauge	4 8½	4 8½	4 8½	4 8½	metre	2 6
Maximum speed, miles per hour	..	25	18	12	21	15
Maximum gradient. . .	1 in 40	1 in 28·6	1 in 20	1 in 20	1 in 20	1 in 20
	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.
Minimum radius of curve .	980 0	650 0	500 0	330 3	230 0	100 0
Width at formation level .	18 0	16 6	14 6	13 0	11 6	10 6
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight of rail per yard .	72½	72½	50–60	40–50	24–40	24–40
	Feet. Ins.	Feet. Ins	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.
Sleepers, length, when of wood	8 2	7 10	7 6	7 6	5 6	5 0
Depth of ballast under sleepers	0 10	0 6	0 6	0 6	0 4	0 4
Locomotives. — Maximum rigid wheel-base . . .	..	11 9	8 6	6 6	6 0	5 0
			Tons.	Tons.	Tons.	Tons.
Locomotives. — Maximum weight on one axle . .	..	..	10	8	6	5
			Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.
Locomotives. — Maximum diameter of driving-wheels	..	..	3 3⅜	2 7½	3 3⅜	2 6

Mr. Money.

Class 1 included railways situated between trunk lines, with a permanent way similar to that of the trunk lines, but with sharper curves and steeper gradients, and otherwise of cheaper construction. They were worked with main-line rolling-stock at a reduced speed, but express engines and those with a rigid wheel-base exceeding 11 feet 9 inches were excluded.

Class 2 included branch lines and lines of secondary importance. They were worked with special rolling stock at a still further reduced speed, but, while of cheaper construction, permitted the passage of main-line carriages and goods wagons.

Class 3 included lines on which the traffic was chiefly goods traffic, and on which, therefore, high speed was not necessary. They were of still cheaper construction, and were worked with special rolling stock, but permitted the passage of main-line goods wagons. The determining factor in this classification was the speed of the trains, for the slower that was, the lighter could the permanent way be made and the cheaper the road-bed. Mr. Deane had referred to American methods of railway construction. The following particulars might therefore be of interest, and enable the cost of construction in the two countries to be compared. The Red River Valley Railway, in Manitoba, ran through a settled country, and had been built in 1887 to the same standard as the Canadian Pacific Railway. It was 65 miles long, and the contract price had been £2,400 per mile complete, including fencing, rolling stock, equipment, etc. It had been surfaced instead of ballasted, and the earthworks had averaged 6,000 cubic yards per mile, and had been sublet at *5d.* per cubic yard. There had been four sub-contractors, who had had to provide all their plant, tools, etc. One of the largest of these four had employed sixty-five teams and 115 men; wages had ranged between 7 shillings and 8 shillings per day for ordinary labourers. The whole of the earthwork, which, including station-yards, had amounted to 400,000 cubic yards, had been completed in six weeks (an average of 11,000 cubic yards per day). Such a result could not have been obtained with so few labourers had not the line been formed principally of banks made from side cutting, by means of four graders and pan-scrapers. The latter put up between 60 cubic yards and 80 cubic yards per day, with a lead varying between 25 feet and 100 feet. Wheeled scrapers, holding about ½ cubic yard, put up between 30 cubic yards and 50 cubic yards per day, and had been used in cuttings. Grading machines put up between 1,000 cubic yards and 1,300 cubic yards per day. They did not make as solid

Mr. Money. a bank as scrapers; it had therefore been specified that on this line the last 2 feet in height of the banks should be finished off with scrapers. On the Winnipeg and Hudson Bay Railway, in the autumn of 1886, 40½ miles of bank, averaging 6,000 cubic yards per mile, had been graded in 21 working days, or an average of 11,500 cubic yards per day. Four graders had been employed in addition to pan-scrapers. Another point in the construction of economical railways was to keep the load per engine-axle as low as possible. For this reason he was glad to see that Fairlie engines were being used on the Tocopilla Railway. On the Quebrada Railway, in Venezuela, a Fairlie engine with four cylinders, 9 inches by 14 inches, weighing, when loaded, 29½ tons, or less than 5 tons per axle, regularly took a load of 61 tons up an incline of 1 in 19, 1 mile long. Mr. Stirling had said that Meyer single-boiler engines had superseded the Fairlie engines on the Tocopilla Railway. It would be interesting to know the advantages of these engines, and any details as to their cost of working would be valuable. The Author had also mentioned the use of tie-plates with four spikes; Mr. Money's experience had shown the advisability of reducing the number of spikes from three to two. If the holes in the plate were made to fit the spike, the plate tied the two spikes together and doubled their holding power. These plates were also useful for prolonging the life of the sleepers when of soft wood. In America, when a suitable plate had been used, the timber underneath it had been found quite solid when that on either side had rotted away.

Mr. Nichols. Mr. O. F. Nichols remarked that the Papers were of special interest at a time when railways required to be built in new and undeveloped countries, where the expenditure on construction and operation was certain, in any event, to be great, and where good results had to be obtained for a minimum expenditure. Great advances in this respect had been made within a few years, and some of the errors of a generation ago had been avoided in these recent illustrations. In one of the earlier Peruvian railways, originally designed with standard gauge, the gauge had been reduced to meet the money procurable for the construction, and in making the change the estimated cost had been reduced in the same ratio as the gauge, an assumption which the contractors had found very hurtful in the execution of the work. It had also been assumed that, because sharper curves could be used on the narrow-gauge line, the gradients could be increased, and where the maximum gradient had been 1 in 25 for the standard

gauge it was made 1 in 20 for the narrow gauge. Fortunately this error had been remediable, and the railway, as far as completed, had no gradient exceeding 1 in 33, which was quite practicable with careful study of the country through which the railway passed. As a rule insufficient attention was paid in such railways to the study of the topography and to carefulness in laying-out. It had been admitted that the cost of easing the curves on the Tocopilla Railway would have been saved many times over in the working-expenses, and under such conditions economy in bridging and tunnelling was rather to be condemned than praised, unless the conditions were extremely rigorous. In lines similar to those of the western coast of South America it was necessary to lengthen the line in order to ease the curves, since the gradients could not be increased beyond a certain low limit. The Arequipa Railway boasted of freedom from tunnels and infrequency of bridges, and this railway might be given as an illustration of the principle that true economy did not necessarily lie in the avoidance of heavy work. It was not surprising that trouble had been experienced from the wear of wheel-tires and rails where such sharp curves were used and such comparatively heavy and rigid engines were required. The Meyer engine seemed to be somewhat of the Mallet type, which, especially when compared with the Fairlie engine, showed great mobility for concentrated weights. The weights of the engines and of the passenger coaches were about the same on the Tocopilla Railway as on the American elevated railways, where, although standard gauge was employed, the curves were sharper. The wear of wheels and rails was, however, much more serious on the Tocopilla Railway, since the rail-life of 70,000 wheels on that railway had to compare with the life of about 3,000,000 wheels on curves of 125 feet radius on the American line, the weight of the engines being about the same. The sole-plate was essential on such sharp curves. It seemed surprising, however, that on both the New South Wales and the Chilian railways the sleepers should be so shallow as 4 inches. The question of water-supply in connection with the Tocopilla Railway was one which seldom occurred in ordinary railway working, and the results given in the Paper were extremely interesting. It was not surprising, considering all the conditions, that the expenses of repairs to engines and cars and the locomotive running-expenses should constitute so large a percentage of the total expenses as that stated. General expenses were certain to be large where conditions were

Mr. Nichols.

Mr. Nichols. so unfavourable to economy as they were in all tropical countries, and 16 per cent. seemed to be a low figure for the cost of coal under the circumstances. This item reached 25 per cent. on the American lines before instanced, but no just comparison could be made of the two illustrations, mainly because coal was so much more expensive in countries where little or no coal was mined. The justification of the adoption of heavier engines and cars on the Tocopilla Railway seemed quite reasonable, and the Author's argument in favour of equipping a line having sharp curves with heavy engines and cars was sound, providing the curves were not too sharp—not less than 250 feet radius on railways similar to that under consideration.

Mr. Robinson. Mr. J. Robinson stated that the cheapest form of railway was that having the sleepers and rails laid just above the surface of the ground without ballasting, with but few culverts and bridges and no fencing. Such lines would be valuable in the initial stage of the development of the resources of an unopened country where the climate was dry and a speed of 10 miles to 15 miles an hour was sufficient for the exigencies of the traffic. He had travelled across plains in Australia where railways of this description could be laid, to be afterwards converted into more substantial lines, suitable for the growing requirements of the settlers. In some cases the lines might have to be practically reconstructed, and in places diverted, in order to make them more direct or to improve the gradients and curves. This would happen in flourishing settlements when the traffic warranted the additional expenditure. Although there were extensive areas in Australia where railways could be formed at a small cost, yet there were long stretches of country to be traversed before reaching these favourable localities, involving heavy expenditure in the formation of cuttings and embankments, in bridging rivers, and in some instances in tunnelling, even when the strictest economy was observed. This was what he had found when exploring Queensland in 1881, in company with the late General W. H. A. Fielding, for the purpose of reporting upon a proposed Australian trans-continental railway. The railway had been intended to run from the Gulf of Carpentaria to join the railway in the south of Queensland communicating with Brisbane, and to be 1,000 miles in length, with branches to meet the railways from Townsville and Rockhampton. An extension of the main line had been projected to the southward from Charleville along the Warrego River into New South Wales to join the railways communicating with Sydney and Melbourne. This portion of the

colony, however, had been explored by a separate party from Sydney Since 1881 some portions of these projected railways had been constructed. With reference to the proposed Australian trans-continental railway scheme he had found that surface lines, which would have cost but a few thousand pounds per mile to construct, were feasible in the interior of Queensland, but lines in other parts would have cost more than twice as much, *e.g.*, a line through the Cloncurry district to Point Parker on the Gulf of Carpentaria, where numerous rivers would have had to be crossed, including the Nicholson, Gregory, Leichhardt, Corella, Cloncurry, Williams, etc. All these rivers he had ascertained, from cross sections which he had taken on the ground, rose to a height of 30 feet in times of flood and spread out to a width of 400 yards to 700 yards. For bridges he had proposed to use the round logs of the country as far as possible, but economical railway construction through this district was quite impossible. Some of the plains traversed had been treeless except along the banks of creeks, and would not have afforded sufficient timber for sleepers along these sections of the line; and the cost in consequence would not have been as low as it otherwise would. A speed of at least 30 miles an hour had been contemplated for the running of trains on the trunk line, which would have necessitated its being properly ballasted, and in a case of this kind it would not be wise economy to dispense with ballasting, as it would be dangerous for trains to run at that speed along such a temporary formation. To save cost in the construction of railways, special attention should be paid to the location, and the necessary expenditure for making the proper studies should not be grudged, as he feared it frequently was. He considered that economical railway construction was needed for the development of new countries, because the prosperity of the settlers depended on the facilities available for the carriage of their goods and produce. Mr. Robinson.

Mr. F. J. WARING thought that Mr. Deane's Paper gave an interesting and valuable description of the manner in which economical construction of railways had been carried out under somewhat exceptionally favourable conditions; although this had in his opinion been attained by some sacrifice of permanency in the character of the work, which must render its maintenance costly. He quite agreed with the Author that a break of gauge was to be avoided, and he congratulated the Colony of New South Wales on having resisted successfully any temptation to effect in this manner even a slight economy in railway con- Mr. Waring.

Mr. Waring. struction. There were few countries through which railways could be built for any distance, even if moderately steep gradients and sharp curves were used, on embankments only between 6 inches and 9 inches in height. Further, if the rainfall of the district traversed were heavy, it would be impracticable, as admitted by the Author, to dispense with ballast, which, besides being otherwise useful, was of much value on curves in preventing lateral displacement of the permanent way; and, in a country where white ants abounded, the adoption of timber structures of the type described would be out of the question. In exceptional instances, it might be cheapest to form embankments entirely from side cutting, all material from the cuttings being carried to spoil; but as a rule, and especially where land was of any value, he did not think this would be the case. In Ceylon, where earthwork was executed by means of baskets carried on coolies' heads, by light hand-carts, and, if the cuttings and banks were heavy, by iron trucks holding about 20 cubic feet, running on rails weighing 14 lbs. per yard, and laid to a gauge of 2 feet, his experience was that, up to an extreme distance of 10 chains, it was economical to lead material from the cuttings to banks, but beyond this it was cheaper to run the material from the cuttings to spoil, and to make up the banks from side cutting. The construction of railways to open up a country where, at the outset, only a small traffic was anticipated, offered a difficult problem to the railway engineer, for while on the one hand it was essential that the first cost of the work should be kept down, it was almost equally important that economy in working and maintenance should be secured; and it was too often the case, he thought, that when a railway for this purpose was contemplated, the first of these considerations carried much more weight with the promoters of the line than it should do, the second consideration being for the time relegated to the background. It was the duty of an engineer in such a case to take a more comprehensive view of the question, and to endeavour to induce his clients to do the same; and in suggesting ways in which the desired cheapness in first cost of construction might be attained, he should remember that although at the outset the traffic to be dealt with was small, it might not improbably develop; and that, therefore, reductions should only be made in those parts of the work which could be easily replaced when required to deal with a heavier traffic. The reductions would thus be principally limited to those parts of the line which were above formation-level, viz., the rails, sleepers and

ballast, and what might be described as the non-essentials of the line, viz., stations, station-yards, buildings, platforms and fencing. It was often possible to omit the last altogether, and when this could be done a further saving in level crossings, wages of gate-keepers and cost of houses for them, was effected. The number of sleepers proposed by the Author with a 30-foot rail, might be the best arrangement in a country where sleepers were cheap and could be obtained locally, as appeared to be the case in New South Wales; but in countries where sleepers had to be imported, and were therefore costly, he thought it would be more economical to use a heavier rail and to space the sleepers somewhat wider apart. Mr. Waring.

Analyses of the cost of railways, in the form of that given by the Author, relating to the Parkes to Condobolin line, were of much value as indicating in a clear manner those portions of the work in which economy in construction could be most satisfactorily and most readily effected; and, taking the figures given, he noted that earthworks cost 14·3 per cent.; bridges and culverts, 5·7 per cent.; stations, 10 per cent.; and permanent way, including materials, ballast and laying, 53·7 per cent. of the total cost. The cost of the line, as given in the Paper, did not, however, include rolling stock, electric telegraph, or land; the total cost of the latter, however, appeared to have been only £40. For comparison with this he ventured to give a similar analysis of the cost of the Kurunegala Railway, in Ceylon, a line on the 5 feet 6 inches

Description of Work.	Cost per Mile.	Per Cent. of Total Cost per Mile.
	£	£
Clearing land	7·1	0·21
Earthwork	274·3	8·12
Bridges and culverts	318·6	9·42
Superstructures for bridges and culverts and freight	81·8	2·42
Permanent way, laying and ballasting	351·0	10·38
" " materials and freight	1,160·3	34·31
Level crossings	27·3	0·81
Metalling roads	15·3	0·45
Stations	344·0	10·18
Miscellaneous works	65·8	1·95
Electric telegraph	11·7	0·33
Land and compensation	119·9	3·55
Engineering and administration	174·1	5·15
Rolling stock	358·0	10·59
Contingencies	72·0	2·13
Totals	3,381·2	100·00

Mr. Waring. gauge, with rails weighing 60 lbs. per yard, a short account of the construction of which he had submitted to the Institution.[1] At the current rate of exchange ruling during the construction of this line its cost had been £3,381 per mile, sub-divided as shown in the Table on the preceding page.

These figures were, he thought, satisfactory, taking into account the fact that the mean annual rainfall of the district traversed was about 90 inches, thus necessitating the provision of nine bridges varying between 12 feet and 60 feet in span, and of seventy-nine culverts varying between 10 feet span and rail openings of 1 foot 10 inches span, and that the line was well ballasted throughout and equipped with its proper proportion of rolling stock. Nearly the whole expenditure under the head of contingencies, as well as a portion of that on account of stations, had not been incurred upon the line itself, but in alterations and additions to the Polgahawela station on the main line of the Ceylon railways, rendered necessary to convert it from an ordinary wayside station into a junction station. The line as constructed had not been fenced, although fencing had been subsequently erected. From the foregoing figures relating to this line it appeared that the cost of bridges and culverts had amounted to only 11·84 per cent. of the total cost of the line, and it was therefore evident that the substitution of temporary structures for the permanent structures built, even had it been otherwise practicable, could have effected only a very trifling saving; on the other hand, the cost of permanent way, level crossings, stations, etc., the items in which he recommended economy, constituted together 59·76 per cent. of the total cost.

In reference to Mr. Stirling's Paper, he thought a length of 24 feet of straight between reverse curves was much too short, having regard to the importance in practice of changing the superelevation as gradually as possible from the one rail to the other, and, at the same time, of giving the full amount of superelevation required throughout the curve. For this reason it had been his almost invariable practice to allow 1½ chain of straight line between such curves, and he might mention that a serious case of derailment on a mountain railway had come within his experience, which, after most careful examination of both permanent way and rolling stock, could only be ascribed to the superelevation of the outer rail having been run out too rapidly on the straight line at the end of a sharp curve.

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxi. p. 283.

Mr. R. STIRLING, in reply to the Correspondence, remarked that the chief advantage of the "Meyer" over the "Fairlie" locomotives was in the marked economy in fuel, which, when using coal, amounted to about 25 per cent. This had been beyond his expectations when designing these engines, but was evidently due to the better form of fire-box and the larger grate-area obtained in the single boiler, and to the whole of the fuel being burned in one fire. Some of the other advantages lay in having only one fire-box and one set of tubes to keep in repair; in the single boiler being lighter in weight than the double form, in proportion to its capacity; and in the driver and fireman being on the same footplate, instead of being separated by the boiler, as in the "Fairlie" engine. These "Meyer" engines had frequently taken trains of 135 tons up the 17 miles of 1 in 25 continuous gradient, with the increased resistance due to the numerous sharp curves; and even the regular load of 120 tons compared very favourably with the load mentioned by Mr. Money as being taken by the "Fairlie" engine on the Quebrada Railway on such a short length of steep gradient. Mr. Stirling.

The "Meyer" system differed from the "Mallet," which did not give the flexibility of the "Fairlie." The only difference between the "Meyer" and the "Fairlie" engines was that the former had a single in place of a double boiler. The boiler and tanks were carried on a frame, which was carried on two bogies, the centres being so placed on the frame that the weight was equally divided between the two bogies. He was not surprised to learn that there was such a great difference between the life of the rails on the curves of the Tocopilla Railway and that of the rails on the sharp curves of the American elevated railways referred to by Mr. Nichols, seeing that the conditions were very different. In New York he had observed that the sharp curves, which were comparatively few, were fitted with guard-rails, the extra friction, in the absence of gradients, not being a serious objection; and both rails and guard-rails were frequently greased. Further, there was no sandy ballast to interfere with this lubrication, and the average weight per axle was less than on the Tocopilla trains. The sufficiency of sleepers only 4 inches thick on the New South Wales and Tocopilla Railways was no doubt due partly to the good quality of the timber obtainable and partly to the dry climate in both regions.

Derailments caused by the superelevation of the outer rail of the curves being too abrupt, such as had been referred to by Mr. Waring, had happened on the Tocopilla Railway with the eight-

Mr. Stirling. coupled locomotives, when the superelevation had been increased or diminished at a greater rate than 1 inch in 24 feet. This prevented the full elevation of 3½ inches being given on some of the shorter curves, but as the maximum speed allowed was only 15 miles per hour, and this elevation had been calculated for 30 miles per hour, it was not of vital importance, although it probably allowed the rails to wear faster than if the full, or a higher, elevation had been practicable, and partly accounted for the wear of the rails being greater on some of the shorter curves, and at the entrance to all the curves.

10 April, 1900.

SIR DOUGLAS FOX, President,
in the Chair.

IT was resolved—That Messrs. G. E. W. Cruttwell, W. T. Douglass, G. A. Hobson, B. Mott, A. H. Preece, J. J. Webster, and L. S. Zachariasen be appointed to act as scrutineers, in accordance with the By-laws, of the ballot for the election of the Council for the year 1900–1901.

(Paper No. 3234.)

"The Development of the Manufacture and Use of Rails in Great Britain."

By Sir I. LOWTHIAN BELL, Bart., LL.D., F.R.S., M. Inst. C.E.

MALLEABLE iron containing usually less than 1 per cent. of foreign matter has been known, as well as its mode of production, from a very early period of the world's history. Nevertheless it is hardly more than 100 years ago that any one could have foretold the probability of this metal being manufactured in sufficient quantities, and at so low a cost, as to admit of its being employed to accommodate the traffic now carried over the railways of Great Britain. The history of the development of the railway system is so interwoven with that of the iron trade that the latter subject must occupy a somewhat conspicuous place in the present Paper.

The geological range of the ores of iron is very extensive, as they exist in rocks of every geological age, from the Archæan gneiss to the most recent post-tertiary deposits. They possess the further advantage of being more easily reduced to the metallic state than any other abundant ores. In numerous localities in the Cleveland hills, as well as elsewhere, vast deposits exist at or close to the surface. If, in such places, an ancient Briton made a fire for cooking his food, the chances are that his rude hearth would speedily receive a coating of malleable iron. In the year 1878, Captain Grant, the companion of Speke in the exploration of the upper waters of the Nile, paid the Author a visit. In reply to an inquiry as to whether any knowledge of obtaining

iron was possessed by a race inhabiting a country where civilized man had never penetrated, he made for the Author a pen-and-ink sketch of a furnace used by barbarians, which was identical in principle with those known to have existed in many parts of Europe. In several cases where, as in Cleveland and the Forest of Dean, all traces of the manufactured metal have disappeared by oxidation, the presence of slag deposits, rich in iron, leaves no doubt as to the prehistoric existence of smelters of iron ore.

Later, out of this earliest contrivance grew a Swedish invention known as the Osmund furnace. It consisted of a shaft, a few feet in diameter, and 8 feet or 10 feet high. In front was a large opening, which was built up while the reducing operation was being carried on. When this was completed, the masonry was removed, and the "Osmund," or metallic mass, was drawn out into bars by hammering.

The Author has not been able to trace any record of carbon being found in the iron thus obtained, but no doubt whatever need be entertained that this element would rarely, if ever, be absent from the product of such a furnace as that described. The Osmund furnace was succeeded by the "Stückofen," or high bloomery furnace, which had a height between 10 feet and 16 feet, and yielded a material so rich in carbon that a second treatment was necessary before it could be converted into a bar under the hammer.

By far the most important step in the metallurgy of iron was the invention of the high or blast-furnace. Its origin and the date of its introduction are uncertain. The first blast-furnaces appear to have been built in Siegerland, about the year 1443, when the existence of twenty-nine "Blasehütten" is recorded. This important development in the manufacture of iron made its way very slowly. Agricola, an Englishman by birth, writing in Latin in 1556, makes no mention of the blast-furnace, for it was unknown at that date in Saxony, in Bohemia, and in Silesia. In France and in Italy, the blast-furnace is shown by Biringuccio to have been in use at the beginning of the sixteenth century. In England it came into use in the middle, and in Sweden at the end, of that century. It may be inferred that the first attempts in this direction were of a very simple kind. To satisfy himself on this point, the Author visited a blast furnace at Aiquebelle, near Chambéry. It was 27 feet high, and the necessary materials—charcoal, ore, and flux—were conveyed up a ladder on men's heads to the top of the furnace. The blast was furnished by a *trompe*, produced by a current of water falling down an upright pipe. The air and water were received in a closed cistern, in which the two separated, the

water flowing away, leaving the air to enter the furnace. The weekly make amounted to 24 tons. In Great Britain the make of the blast-furnace 60 years ago was comparatively small, rarely exceeding 50 tons in one week. In Middlesbrough, furnaces are now to be found which are yielding 700 tons to 900 tons per week from the Cleveland ironstone, containing about 30 per cent. of metallic iron.

It may be interesting to consider shortly the means by which this great improvement has been realized. In the first place the fuel was exclusively charcoal up to the year 1612, when Dud Dudley attempted, but failed, to employ mineral coal in his furnace; and complete success in using mineral fuel was not achieved until 1735, when Abraham Darby introduced the method of charring the coal, as had been done with wood in the process of making charcoal. Secondly, the use of heated blast, suggested by J. B. Neilson, effected a great economy of fuel, the cause of which was long regarded as mysterious.[1] Thirdly, the use of the otherwise escaping gases of the furnace, previously wasted, for raising steam for the blast-engine and heating the air, effected a saving of 12 cwt. of coal for each ton of iron made.

The steps in the production of the necessary materials for railway construction having been briefly mentioned, the utilization of these materials by the engineer may next be considered.

The Wylam Colliery lies at a distance of 6 miles west of Newcastle-on-Tyne. At this establishment the owner, Mr. Blackett, had constructed, with the assistance of the engine-wright, Mr. Hedley, a locomotive engine by means of which the produce of the mine was conveyed to the shipping staithes on the River Tyne. Near the wagon-way traversed by this engine is a cottage in which George Stephenson was born. Having made the acquaintance of Mr. Nicholas Wood, a leading mining engineer of Northumberland, Stephenson was employed at Killingworth Colliery, then carried on under the superintendence of Mr. Wood. Shortly afterwards, he was appointed to devote a considerable portion of his time at the Walker Ironworks of Losh, Wilson and Bell. There, with the aid of Mr. William Losh and Mr. Nicholas Wood, many improvements, long since superseded, were made in the equipment of the early railway.

At the period when the manufacture of iron had not gone beyond the blast-furnace, no means existed of converting the pig

[1] See the Author's work on the "Principles of the Manufacture of Iron and Steel," p. 80.

into malleable iron at a price which permitted its adoption as a material for rails. This advance was effected by the introduction of the process of puddling in 1784, the invention of Richard Cort, to whom, be it remembered, is due the design of the first mill for rolling iron in the form of bars. Some years no doubt elapsed in improving these inventions. They were sufficient, however, to enable Mr. Birkenshaw, manager of a small rolling-mill in Northumberland, to test the practicability of laying the line between Newcastle and Carlisle, the first portion of which was completed in the year 1835, with malleable-iron rails.[1]

Previous to the year in question, the Directors of the railway had to consider the arrangements for carrying on the traffic. They were fully alive to the fact that the line had to surmount a range of elevated ground far higher than that traversed by any railway already constructed. At a distance of 42 miles from Newcastle, the railway attains a height of 450 feet above mean sea-level. This passed, there follows a stretch of level ground 6 miles in length, after which, at a distance of 12½ miles, Carlisle is reached. The descent of 450 feet in 12½ miles constituted a very heavy gradient for the locomotives of that time. A deputation of the Board visited all the lines then in existence in this country. From this investigation they returned to report to the shareholders and to recommend the exclusive use of horses in working the traffic.

In the meantime, two Newcastle firms had commenced the manufacture of locomotive engines. One firm consisted of Mr. Stephenson and the father and uncles of the present Chairman of the North Eastern Railway Company. The other was a firm of stationary-engine builders, viz., Messrs. Hawthorn and Company. This fact appears to have altered the views of the Directors, for they forthwith ordered locomotives of the two firms, so that the horse-traction plan was never put in practice.

For upwards of 30 years the position of malleable iron as a material for rails remained unchanged, when, in the year 1856, Mr. Henry Bessemer read a Paper before the British Association describing a mode of producing iron and steel without fuel.

Subsequent events showed that an addition of spiegeleisen, rich in manganese, as suggested by Mr. R. F. Mushet, would render it possible to produce by this process a material of perfect malleability and superior in strength to any rail of malleable iron.

There was, however, one hope Mr. Bessemer had to abandon,

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[1] These works being incapable of producing rails on a large scale, the order was sent to Dowlais in South Wales.

viz., the successful application of the process to produce a satisfactory rail from the ordinary Welsh or similar qualities of pig-iron. It was found necessary to employ pig-iron made from the richer and purer ores of Cumberland and Lancashire.

Mention has already been made of the time which elapsed before Cort's invention of puddling arrived at the perfection it attained in more recent times. To prevent the rapid corrosion of the masonry of the puddling furnace, partial oxidation of the constituents in the pig-iron was carried on in a low fire known as the refinery. Now everyone familiar with the action of a refinery must have observed a very rapid and intense elevation of temperature when the pig-iron once melted began to suffer the same change in principle as that which takes place in a Bessemer converter.

On the wonderful pyrotechnic spectacle presented by a converter at work it is unnecessary to dwell, but this must not imply ignorance that a current of air driven into molten cast iron is accompanied by an enormous evolution of heat.

The one idea which Mr. Bessemer sought to realize was the production of rails from malleable iron obtained in its liquid form. At an early period in the progress of this discovery the Author applied himself to an endeavour to ascertain whether, having regard to the quantity of heat required for fusing pure iron, combustion of the carbon originally contained in the pig-iron was equal to this duty. In the Author's opinion the heat thus generated would fall far short of that required for melting pure iron.

In producing 1 ton of steel the Author has estimated the Centigrade calories to be evolved by—

	Cwts.		Calories.	Matter not oxidized after Conversion of Pig-Iron into Steel.
Oxidation of carbon . . .	3·800 × 4,150	=	15,770·0	0·500
" " other metalloids	3·760 × various	=	25,202·1	0·169
" " manganese . .	0·900 × 1,724	=	1,551·6	0·870
" " iron wasted . .	11·540 × 1,582	=	18,256·2	..
			60,779·9	

This quantity of heat, viz., 60,779 calories, suffices to fuse steel.

Now supposing the manganese and metalloids left in the steel had also been expelled and nothing but pure iron left, the heat by their oxidation would only be equal to the evolution of something under 4,000 calories, a quantity which, it is needless to say, could not make itself felt in raising the temperature of the converter, and therefore absolutely inadequate to fuse the iron freed from all foreign matter. The Author believes it will not be disputed that the element which plays the most conspicuous part in promoting the fusion of pure iron is carbon Under these circumstances it is

essential that the removal of the other constituents of pig-iron should take place before the disappearance of the carbon.

In order to study the circumstances which influence the comparative rapidity of the disappearance of carbon and phosphorus from the liquefied metal, the Author made a number of experiments described in a Paper[1] read before the Iron and Steel Institute in 1877. The Author presented the information thus obtained in the form of diagrams (Figs. 1, Plate 6).

No. 1 represents the action as it took place in the Bessemer converter, in which the whole of the carbon disappeared in 17½ minutes after the blast was turned on. There was an increase in the proportion of phosphorus in the steel of about 10 per cent. due to the loss of weight in the operation.

No. 2 exhibits the action of the refinery already described. In this a considerable quantity of iron oxide was generated, and this substance acidified the phosphorus so readily that in 29 minutes 42 per cent. of this element was removed. On the other hand, 20 per cent. only of the carbon had disappeared in the 29 minutes.

No. 3 shows the results obtained by the puddling furnace. The acidification of the phosphorus took place until the end of 15 minutes, after which the proportion of that element increased in amount. The Author attributes this to the higher temperature of the furnace towards the close of the operation, when the action between phosphorus and oxygen is reversed. Finally 96 per cent. of the carbon contained in the pig-iron was oxidized at the close of the process at the end of 30 minutes.

No. 4 exhibits a process devised by the Author for ridding the bath of iron of phosphorus more completely than in any of the three previous examples. He has distinguished it by the name of "purifying" or "washing." Here in 13 minutes 95 per cent. of the phosphorus was separated from the metal, while 97 per cent. of the carbon disappeared in 20½ minutes. A slight increase in the phosphorus was noticeable in 17 minutes, due, it is believed partly or wholly to the cause mentioned in No. 3.

Mr. Bessemer secured patents in various iron-making countries, and among them one in Sweden. There, by the use of very pure ore, and with charcoal for fuel, bar iron of a very high quality was produced. Mr. G. F. Göranson, an eminent manufacturer in that country, had purchased a share in Mr. Bessemer's Swedish patent, and, in consequence, an engineer with the needful appliances was sent over from England to enable him to commence the practice of

[1] Journal of the Iron and Steel Institute, 1877, p. 342.

the newly invented process. By steady perseverance success was at length achieved by this gentleman, and this without the admixture of any foreign matter. The fact is, the impurities in the pig-iron used were so trifling in amount that the carbon it contained was not entirely consumed until all deleterious matter had been removed. Mr. Göranson then conveyed to London 30 tons of his steel; and it seems clear that this was the first steel produced according to Mr. Bessemer's published specification, and it was produced with the very appliances supplied by the patentee.

How far the idea of turning attention to pig-iron made from the purer ores of the West of England was suggested by the experience of Mr. Göranson, the Author is without the means of judging; at the same time it is probable that the success in Sweden led Mr. Bessemer to try the purer varieties of British iron.

In a communication made to the Author by Mr. Bessemer, he mentions the researches he instituted to obtain Bessemer pig-iron. Of the first samples several thousand tons were despatched to the United States, and the results of his labours were communicated to the Dowlais Company. These consisted merely in changes in the mode of charging the fuel, ore, and limestone, into the blast furnace. He does not pretend, nor does the Author think he meant, that metal so obtained could be employed in his converter without admixture of spiegeleisen or ferro-manganese. Speaking from an experience of 12 years at the Barrow Steel Works, the Author gives it as his own opinion, that the alteration spoken of by Mr. Bessemer could not be followed by the effect claimed by him, and further, that no ore found in that district could give metal so pure as to dispense with the addition recommended by Mushet.

Guided by the information derived from the experiments already referred to, the Author proceeded to try, at the works of Messrs. Baring in the county of Durham, the effect of running fused oxide of iron into the converter. The action was so violent as to amount to an explosion, by which a large portion of the contents were projected from the vessel.

With regard to the properties of Bessemer metal, one circumstance has been made sufficiently apparent, viz., the extreme irregularity in the strength of rails so produced. The Author will illustrate this by citing the amount of force required to produce fracture. Some description seems necessary of how the aggregate fall of the weight is estimated.

The rail to be tried is laid on supports 3 feet apart, placed on a

heavy metal foundation. A weight of 1 ton is then raised between two lofty guides to a given height and suddenly detached. The deflection is measured and noted. The weight is again raised and this is repeated until fracture takes place. As there are no means of ascertaining how much of the last blow is absorbed by the rail, one-half of the last fall is taken in reckoning the total height of fall producing fracture.[1]

It must be borne in mind that the sum of the heights of the several falls by no means represents the real force expended on the rail; because no account is taken of the increased power generated by the continued action of gravitation during the fall. Even were this included no more exact expression of the force exerted would be arrived at, because the amount to produce deflection is an unknown quantity.

The following Table gives examples of the fall, in feet, needed to produce fracture in rails:—

Rails of 82 lbs. per yard—							
Number of rail .	1	2	3	4	5	6	7
Fall of weight for fracture . feet	30	30	37½	45	..	..	..
Rails of 90 lbs. per yard—							
Number of rail .	1	3	2	3	2	2	1
Fall of weight for fracture . feet	23½	50	91½	104½	107½	165½	199
Composition: Average carbon and phosphorus—							
Carbon	0·510	0·483	0·500	0·502	0·475	0·485	0·490
Phosphorus . .	0·073	0·065	0·080	0·081	0·082	0·068	0·085
Total carbon and phosphorus .	0·583	0·584	0·580	0·583	0·557	0·553	0·575

To carbon, when in moderate quantities, hardness and strength are attributed, and to phosphorus brittleness; but the difference in power of resisting fracture, as measured by the fall of the weight, does not correspond with the analyses taken as a whole. The discrepancies are not merely apparent as between separate rails,

[1] Example of estimating aggregate feet of fall of 1 ton required to break a rail:—

First blow		5·0 feet.
Second „		5·0 „
Third „		7·0 „
Fourth „		10·0 „
Fifth „		15·0 „
Sixth „	21, taken at one-half	10·5 „
		52·5 „

inasmuch as different parts of the same rail vary considerably when tried under the falling weight.

The Author's friend, Professor H. M. Howe, of Columbia College, New York, in his classic work on the manufacture of steel, pointed out that the upper portions of an ingot intercept, on cooling and becoming viscous, considerable quantities of gaseous matter. These fill spherical cavities, which in rolling are flattened without any actual welding of the sides of the cells being necessarily effected.

Six ingots were indiscriminately selected and divided into three sections marked tops, middles, and bottoms, forming thus eighteen separate rails.

The rails rolled out of the different portions of the ingots broke under the falling weight of 1 ton as follows:—

Tops.	Middles.	Bottoms.
Aggregate Fall in Feet.	Aggregate Fall in Feet.	Aggregate Fall in Feet.
52½	76½	76½
13½	52½	103½
52½	52½	52½
22	76½	76½
76½	76½	76½
76½	52½	76½
Average.		
48·9	64·5	77

If, for comparison, the average of the tops be represented by 100, the average of the middles will be represented by 132, and that of the bottoms by 157. The average composition of these rails was:—

—	Tops.	Middles.	Bottoms.
Phosphorus	0·050	0·057	0·056
Carbon	0·538	0·555	0·565
Sulphur	0·053	0·058	0·058
Silicon	0·071	0·072	0·070
Arsenic	0·050	0·043	0·049
Manganese	0·982	1·020	1·030
Matters other than iron	1·744	1·805	1·828
Difference for iron	98·256	98·195	98·172
Total	100·000	100·000	100·000

There is nothing in the Author's judgment in these analyses to account for the great differences in strength.

In these pages iron and steel have been properly considered separately. In the following Table the results of tests of twelve iron rails and fifteen steel rails are shown side by side:—

Iron Rails. (Twelve.)				Steel Rails. (Fifteen.)			
Fall of Weight (1 Ton).	Years in Use.	Position of Running Head.	Annual Loss per Yard.	Fall of Weight (1 Ton).	Years in Use.	Position of Running Head.	Annual Loss per Yard.
Feet.			Lb.	Feet.			Lb.
5·0	19·0	up	..	2·0	10·00	up	..
0·5	19·0	down	..	0·5	10·16	down	..
4·0	19·0	up	..	2·0	11·25	„	..
0·5	19·0	down	..	65·0	15·33	up	..
0·5	19·0	down	..	4·5	15·00	down	..
2·0	19·0	„	..	0·5	17·33	up	..
2·0	24·0	„	..	2·0	17·58	down	..
0·5	24·0	„	..	44·5	19·08	„	..
1·0	24·0	„	..	44·5	19·00	„	..
4·5	24·0	„	..	2·0	20·50	„	..
0·5	24·0	„	..	44·5	19·83	„	..
8·0	24·0	„	..	5·0	21·16	„	..
..	..	..	..	26·0	21·41	„	..
..	..	..	..	2·0	21·41	„	..
..	..	..	..	0·5	23·58	„	..
Average.							
2·42	21·5	2 10	0·152	16·36	17·51	3 12	0·402

In point of years of service, the iron rails have an advantage over those of steel, the ages being 21·5 years as against 17·51 years. On the other hand, the strength, as determined by the falling weight, is 2·42 as against 16·36. The position of the running head in receiving the blow being considered of importance, this has been inserted. In the present case this is immaterial, owing to the close similarity. Further observation on the position of the running head will be reserved until an extensive trial on the main line between Darlington and York is described.

The annual waste per yard differs greatly, that of iron being 0·152 lb. per yard, and of steel 0·402 lb. In the former, the effect of the traffic is a splitting up of the rail at the numerous weldings entailed by the mode of manufacture, whereas steel, by the action of the train, is ground down to an impalpable dust, which is dispersed, and so lost.

Four other examples of iron and two of steel are given below, of which the averages alone are inserted :—

Malleable Iron.						Steel.					
No. of Rails.	Fall of Weight.	Years in Use.	Position of Running Head.		Annual Loss.	No. of Rails.	Fall of Weight.	Years in Use.	Position of Running Head.		Annual Loss.
	Feet.		Up.	Down.	Per Yard.		Feet.		Up.	Down.	Per Yard.
10	0·62	24·40	10	..	0·148	15	29·70	17·58	..	15	0·257
12	2·06	21·77	12	..	0·104	20	30·33	15·28	20	..	0·444
12	0·50	27·00	12	..	0·133	..	..	..	..	..	..
12	1·23	30·41	12	..	0·209	..	..	..	..	..	..

In respect to the longevity of iron rails, the Author's conclusions are founded on the behaviour of 178,584 tons of this material. The laying down of iron rails was discontinued on the North Eastern system in 1877, and taking the average life at 19 years, the whole quantity ought to have been removed in the year 1896. As a matter of fact, at the end of that year there still remained in use upon the railway a considerable weight of iron rails, so that it will be safe to say that the average life of the 178,584 tons will be at least 20 years, or fully 2 years more than that of steel rails.

Steel Produced by the Open-Hearth Furnace.—An idea originating in 1817 with a Scottish clergyman of the name of Stirling was subsequently improved to such an extent that it led to what is now known as the Siemens furnace.

In all reverberatory furnaces the loss of heat at the chimney is enormous. This new, or regenerating furnace, as Sir William Siemens styled it, is now so well known as to render a detailed description superfluous. It is true that the conversion of the carbon of the fuel into gas entails a great loss of power—say about 70 per cent.—but this is far more than compensated for, as the heat is largely returned to the furnace, and a temperature far exceeding that obtained in the ordinary way is attained.

The Author visited, in 1867, the works of Mr. Emile Martin at Firminy, in France, and found him melting a mixture of pig and malleable iron, both obtained from the pure ore of Mokta, in such proportions as to produce steel. In more recent times, decarburization of the pig has been largely effected by the addition of iron ore, the pig used being exclusively that from the hæmatites of the west coast. The operation of conversion requires nearly as many hours as the Bessemer conversion takes minutes. The result is that the workman at the open-hearth furnace has ample time to test the

character of the product. For all purposes where great strength and unfailing regularity of quality are desired, the Siemens-Martin steel is specified. Such purposes include ships, locomotives, &c. Pig-iron of the best quality alone is referred to in the foregoing remarks on the Siemens-Martin process. More recently pig-iron made from Cleveland ironstone, and containing as much as between 1 per cent. and $1\frac{1}{2}$ per cent. of phosphorus, has been used; and no difficulty is now experienced in reducing this element at will to between 0·010 per cent. and 0·020 per cent. in the steel.

Extreme Brittleness of Steel Rails after Use.—At the beginning of the Author's labours in 1894, he must confess to his great alarm on finding how brittle rails were which had broken while in use. It was found that out of twenty-four rails broken, the fall in feet required to produce fracture was as follows:—

	Under 6 Feet of Fall.	Maximum Feet of Fall.
Ranging from 6 inches to 5 feet 9 inches, average	=2·43	30 to 111·5 Average =71 feet.
Age „ 7·92 years to 22·75 years, average	=12·85	2·33 to 21·16 Average 14·58 years.

The impact of a falling weight is exclusively of the nature of a blow, which, as is well known, differs greatly in its effect from simple pressure. It was ascertained that a rail which broke under a falling weight resisted fracture when placed under hydraulic pressure amounting to 20 tons. Ten rails were operated on, the average fall of the weight to produce fracture being less than 1 foot.

The amount of grinding work which rails have to encounter is extraordinary. Taking the entire North Eastern Railway system, *i.e.*, main lines and branches, and assuming the average life of a steel rail to be 18 years, the Author estimates that the rails on the North Eastern Railway system, in the period ending the 31st December, 1898, had been exposed to the grinding effect of 464,170,000 train-miles. Necessarily this is not equally distributed over the entire system. Hence, if a place like Newcastle be selected, and another at the termination of a remote rural district, the difference in train-miles run must be very great. Many attempts were made to bring this within the range of actual figures, but any approach to the truth was found impracticable. Recourse was then had to a tabular statement of rails found broken while in use. This is not presented as an unfailing indication of the relative amounts of traffic, but it is the best test that the Author, with the assistance of experienced officials, has been able

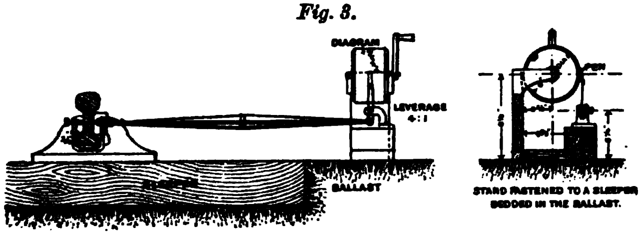
to devise. The details are set forth in the accompanying map (Fig. 2, Plate 6), the figures in each square showing the number of rails found broken on the lines of railway within it, during a period of 25 years (1871–1895), the total number in that period being 917. Some discrepancies may be detected. As an example, at a small wayside station at Warcop, near Penrith, about fourteen breakages occurred in as many days. On inquiry, it was found that snow fell heavily during this time, which prevented the platelayers from securing a firm bed for the sleepers.

Government Interference.—There is one difficulty of an important character which Railway Boards have now to submit to. This lies in the interest taken in their labours by the Board of Trade.

In the exercise of their duties, railway companies are forbidden to turn double-headed rails, *i.e.*, to reverse them, after one head has suffered the prescribed amount of wear, so as to expose the other head to the traffic. There are certain objections to the plan, unless properly dealt with. This has been effectually done on the North Eastern Railway system, and the result on the main line between Darlington and York attests the accuracy of this statement. On it 883 tons consist of turned rails, the remainder, about 9,150 tons, not having been turned. The average age of the whole at the time the report was made amounted to 20·26 years, and the total loss per yard 6·63 lbs.

Effect of Heavier Locomotives and Increased Speed of the Trains.—Some difference of opinion having been expressed respecting the effect of the greater weight of modern locomotives, and the higher speed of the trains they are made to draw, the second of these two points was made the subject of inquiry.

Fig. 3.

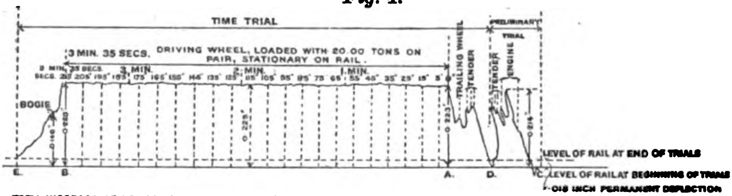


That an addition to the weight of engine and train must be attended by an increase in the wear and tear of the permanent way admits of no doubt, but the Author was not inclined to agree that a higher speed would be accompanied by an addition to the wear of the rails. He therefore suggested a form of apparatus for measuring and recording the deflection of the rails at various

speeds. In designing this machine he received valuable assistance from Mr. Wilson Worsdell, M. Inst. C.E., chief of the locomotive works of the North Eastern Railway. *Fig. 3* shows the details of the apparatus.

Fig. 4 exhibits a time trial of deflections of a locomotive and

Fig. 4.



TOTAL INCREASE OF DEFLECTION IN 3 MIN. 35 SECS. WITH ENGINE DRIVING WHEELS STATIONARY OVER INDICATOR 0·005 INCH.

tender, in which, at stated intervals, the driving-wheel remained stationary over the indicator.

The following are the results obtained by the passage of a train, in which the weights were:—

	Tons.	Cwt.
Locomotive, running weight	46	12
Tender " "	33	18
Total weight of six carriages	22	7¾

PARTICULARS OF TRIAL.

Speed of Train.	Vertical Deflection.	Deflection per Mile of Speed.	Lateral Deflection on Curve of 90 Chains.
Miles per Hour.	Inch.	Inch.	Inch.
4·2	0·25	0·059	0·04
8·3	0·25	0·030	0·03
14·9	0·25	0·016	0·05
17·3	0·26	0·015	0·05
26·7	0·27	0·010	0·05
32·4	0·27	0·008	0·06
40·4	0·25	0·007	0·08
45·0	0·30	0·007	0·09
57·1	0·33	0·006	0·15
65·2	0·30	0·004	0·15

It would be difficult to speak positively as to the difference in weights of the engines, taken as a whole, running on the North Eastern Railway system in 1870 and 1900. The same may be said of the speeds of all trains—passengers, merchandise and minerals. Taking the average speed at 40 miles per hour, and the corrected deflection at 0·28 inch, an increased pressure on the metals of 11 per cent. is obtained, as compared with the deflection in the first three instances given, viz., 0·25 inch. The deflection

per mile of speed on the straight line is, of course, very small on each mile of increase. This, however, cannot be accepted as an indication of the actual pressure—and therefore of the actual wear on the rails—which is set forth in the second column of the Table. The Author, not being convinced that, in all cases, higher speeds of trains meant increased destruction of rails, applied to his friend Sir Andrew Noble, at an early period of the present enquiry, who confirmed this opinion in the following reply:—

"The question you ask is a somewhat difficult one to answer, because it may be complicated by vibrations which, under certain conditions, might be cumulative; but if you disregard these, and if you further suppose that there is no curve on the line, I think it cannot be doubted that the higher the speed the less is pressure on the rail. If the speed of the train were infinite, there would be no pressure at all on the rail, and at the high speed some of our trains run, I can easily conceive a train passing safely over a broken rail which would fail altogether in the case of a train moving slowly. The same argument applies to a weak rail. Before it breaks it has to bend to a certain extent. If the velocity is very high the time the weight is on is short, moves the rail only through a short space, and so the work done on it is much less than if the speed were slow. I need not say the higher the speed, the more rails on a curve are strained laterally."

The diagram (*Fig. 5*) shows a curve of deflection due to the passage of an engine and tender, and it would appear that there is not much cumulative vibration to be apprehended, to which Sir Andrew Noble calls attention. The train of which it is the record was only travelling at the rate of 45 miles per hour. At this rate an ordinary passenger train would pass over a given point in about 6 seconds; but, in point of fact, the only heavy part of the train, viz., the engine and tender, would not occupy more than a very brief fraction of a second.

As regards the curves, as might be expected, there is a marked increase in the deflection with increase in the speed. The super-elevation of the outer rail in this particular instance was $1\frac{1}{2}$ inches.

It has been alleged by Sir Henry Bessemer himself that Railway Boards showed an indisposition to use his steel rails on their respective lines, and that external pressure during the currency of his patent became necessary to ensure their adoption. So far as the North Eastern Company is concerned, it was not until 1877, or 21 years after the date of the Bessemer patent, that the use of iron rails was entirely abandoned. The Author thinks he can give to this charge of needless delay an answer which

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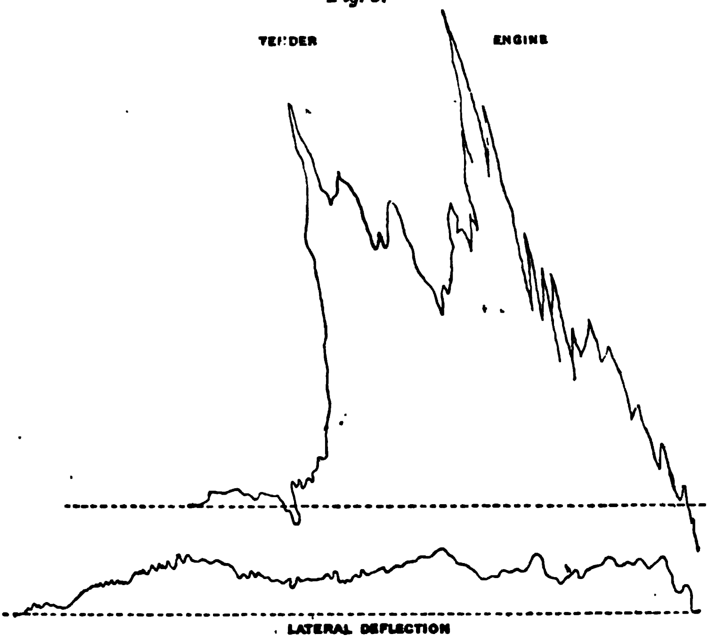
it will be difficult to refute. He will pass over the time required for erecting the necessary works, the complete failure at first to realize the expectations of the inventor, and the investigation of Mushet's discovery. These obstacles overcome, the directors had to consider the relative cost of iron and steel. At an early period, it must have dawned upon the North Eastern Railway engineers, that in the matter of longevity, the superiority lay with the former. Then arose the question of the relative cost of the two. In dealing with this, it must be recollected that the properties of

Fig. 5.



steel required it to be manipulated in a fashion requiring very extensive and costly changes in the rolling mills machinery; a further addition to the cost of production, not of much importance, it is true, but worth a passing remark, is that 20*s.* was demanded for patent right instead of the 10*s.* originally quoted. The difference in the prices asked by the manufacturers for steel rails was as follows:—

		Per Ton. £	*s.*	*d.*
1870 to 1874	Steel above iron	4	0	0
1877	. . " " "	0	10	0
1888	Actual price at which rails were bought . . .	3	15	0

It cannot be pretended that £3 15*s.* leaves any reasonable margin for the manufacturer's profit; but the Author has calculated that suitable ore can be brought down from the mines in the Bilbao district, put into a vessel on the Nervion river, unloaded in the Tees, and converted into steel rails, at a lower cost than iron rails can be obtained from Cleveland ironstone lying within a mile or two of the gates of the rolling-mill where they were wont to be manufactured.

Molecular Change in Rails by Use.—The former engineer-in-chief of the North Eastern Railway system, Mr. T. E. Harrison, in a report prepared for his directors, expressed the opinion that rails by wear became impaired in strength to a degree beyond that due to their mere loss of weight.

Sir William Roberts-Austen and Mr. Stead, of Middlesbrough, have added immensely to our knowledge on this subject by the use of microphotography. The former has ascertained that besides the mere mechanical alteration there is actually a rearrangment of a chemical character in the elements found in the rail, and Mr. Stead has shown that by the crystalline change a direction is given to a cleavage which may end in fracture.

This view was propounded before the Institution by Mr. W. G. Kirkaldy in a Paper[1] he read in January, 1899, and was commented on by Sir William Roberts-Austen,[2] who exhibited a series of enlarged photographs showing the nature of the various changes. The information then placed at the disposal of the Institution renders further notice by the Author unnecessary.

A word or two on a discovery described by Dr. T. E. Thorpe to his fellow-members of the Committee appointed by the Board of Trade to enquire into the loss of strength in steel rails through use on railways, of which Committee the Author was also a member. During the discussions of that body the Author adduced certain figures to show that brittleness in a steel rail does not appear to be invariably traceable to a high percentage of phosphorus. In the notes on the evidence afforded by the chemical and micrographical examination of steel rails, by Sir William Roberts-Austen and Dr. T. E. Thorpe, this is substantially agreed to.[3] These gentlemen, as well as other authorities, proceed to show that phosphorus may exist in different forms, one

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxvi. p. 141.

[2] *Ibid*, p. 174.

[3] "Report of the Committee appointed by the Board of Trade to enquire into the Loss of Strength in Steel Rails through use on Railways," 1900.

or more of which may be harmless. The Author would have a difficulty in making this quite clear to the general reader. He will therefore conclude by an expression of belief that the smaller the total quantity of phosphorus of all kinds, the less will be the chance of having a dangerous amount of the objectionable variety.

For some years railway companies have been called upon to furnish an annual statement of rails which have broken on their lines. The Author estimates the number of rails broken annually in service at 1 in 25,000, calculated on all the railways in Great Britain. A few years ago an accident took place on the Great Northern line, in which for the first time a loss of life occurred. After a protracted enquiry by a committee, certain recommendations were arrived at, but the committee were not unanimous, one at least of them being averse to any change being made in the management of the permanent way.

The Board of Trade now absolutely refuse to certify a new line as fit for passenger traffic, if it is laid with rails which have been in use on other parts of the line. Such rails may be lifted in the ordinary maintenance of a main line and replaced in the position hitherto occupied. Against this there is not, and cannot be, any prohibition; but their removal to a new situation of insignificant traffic, and consequently small annual wear, is absolutely forbidden.

Mr. Gruner, the late Professor of Metallurgy in the École des Mines at Paris, has laid it down as a fixed law that silicon, on being oxidized, effectually drove the phosphoric acid, should any be absorbed by the slag, back into the metal. This is amply confirmed by the Author's experiments, partly already described.

On these truths depends the basic process of steel-making known as that of Thomas and Gilchrist. By its means the phosphorus, instead of poisoning the steel, is kept in the slag and rendered valuable as a fertilizer of the soil. The invention is further of national importance. British ores of the hæmatite class are being rapidly exhausted, so that before long, unless new deposits are discovered, recourse will have to be had to the phosphoric ores of Cleveland and Lincolnshire. The North Eastern Railway Company has used many thousand tons of rails manufactured by the basic process, the durability of which has been proved equal to that of steel rails manufactured from hæmatite ore.

The Paper is accompanied by illustrations from which Plate 6 and the Figures in the text have been prepared.

(*Paper No. 3180.*)

"The Wear of Steel Rails in Tunnels."

By Thomas Andrews, F.R.S., M. Inst. C.E.

The ordinary wear of rails placed in tunnels is complicated by various factors, such as the increased corrosion of the surface of the rail, arising from the action of moist chemical vapours, and the increased chemical action of the ballast on the foot of the rail. The ballast in tunnels, owing to its general porous nature, absorbs the chemical vapours, and hence acts as an increased deteriorative force on steel rails.

The influence of tunnels on the wear of rails is varied and not always easily to be accounted for. The deterioration by the corrosive action of chemical vápours is sometimes greater in dry tunnels than in wet tunnels. This may possibly be accounted for by the suggestion that in wet tunnels the chemical vapours become absorbed in the water and more rapidly drain off, owing to the constant supply of drainage-water, which tends to draw off the chemicals. In dry tunnels the chemical vapours are more likely to be absorbed and retained in a more concentrated form in the porous mass of the ballast, sleepers, &c. The deteriorative action due to corrosion in tunnels is of course increased by the local galvanic action (which is set up by the action of moist chemical vapours) between the steel rail and the metal chair, the latter acting as the negative element of a galvanic couple, and the steel answering to the positive element, owing to its being more easily attacked, chemically, than the cast metal. The effect of a tunnel will also be influenced by the relative direction of that tunnel as compared with the direction of the prevailing winds in the locality; and also by the contour of the surrounding country. Thus a tunnel in a low-lying valley, running through a high mountain, is not likely to have such ventilation as a tunnel situated in a higher and more exposed position. The effect of corrosive deterioration on rails, whether in the open air or in tunnels, is of course influenced by the situation of the line, such as contiguity to a sea-atmosphere, or the passing of the line

through districts in which there are large chemical manufactories, iron-works, steel-works, collieries, or other works which increase the atmospheric impurities.

Again, the effect of a tunnel on rails will depend considerably on its length, as in shorter tunnels there is greater opportunity for the chemical vapours to escape; and it will also be influenced by the nature and depth of the natural strata lying overhead. In all cases, however, it is essential that the permanent way should be carefully watched in tunnels, as the factors of deterioration are greater there than in other parts of the line. The nature of the strata forming the floor of tunnels also more or less influences the life of the rails.

It has been observed that the action of the acid vapours and products of combustion is chiefly noticeable on the bottom flange of the rail where its surface rests in the chair. This is illustrated by Fig. 6, Plate 7, which is a typical instance of this corrosive effect. In the present Paper some idea of the increased rate of corrosive action is afforded.

In order to investigate the effects of tunnels on the wear of steel rails, the Author made a careful examination of a rail which had done its life's work in such a situation. The portion examined was cut from the end of a Bessemer steel rail, supplied by the chief engineer of an English railway. The rail had been laid in a tunnel for 7 years on a straight piece of road, having a falling gradient of 1 in 90, and it had carried the main line traffic for the above period without fracture. The tunnel is about 1,000 yards in length, and is situated fairly near the sea-coast. A large traffic passes through the tunnel, which is constantly filled with a mixture of smoke and steam for at least 18 hours out of the 24. The length of the tunnel lies, in relation to the magnetic meridian, nearly due north and south.

This relation of direction to the magnetic meridian is mentioned because in a long research, the results of which were communicated to the Royal Society,[1] the Author observed indications that magnetization exerts an influence tending to increase the corrosibility of steel in certain solutions; and, as is well known, steel retains more or less permanent magnetism after having been magnetised. It may therefore be possible that steel rails gradually become magnetic from the influence of the earth's magnetism, when laid in a direction bearing a suitable relation to the direction

[1] "Electro-chemical Effects on Magnetizing Iron," Proceedings of the Royal Society, vol. xlii. p. 459, vol. xliv. p. 152, and vol. xlvi. p. 176.

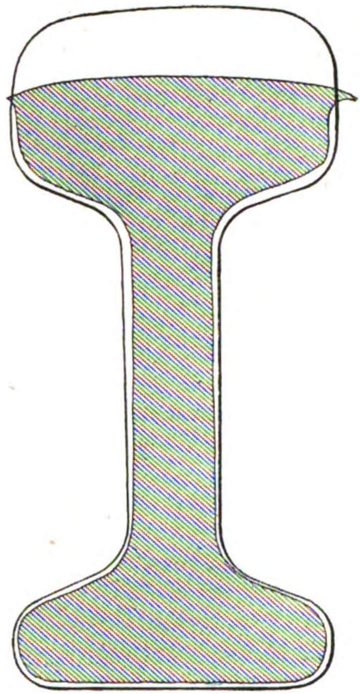
of the magnetic meridian, and hence the corrosion in rails when so situated may be somewhat increased.

The rail had not been turned from end to end during its life, and the rolling stock had always passed over it in one direction.

General Examination.—The original section of the rail, *Fig. 1*, was 84 lbs. per yard. It weighed about 64½ lbs. per yard when taken out, which represents a loss, from wear and tear and corrosion, of about 2·8 lbs. per yard per annum. This is comparatively an excessive annual loss.

On the face the rail had worn down from the original section to the extent of $\frac{5}{8}$ inch—a reduction which is also abnormal. The section of this rail when taken out was as generally indicated by the shaded portion of *Fig. 1.* The constant pressure and stress of wear had flattened or transversely rolled out the surface of the rail-face, so that it protruded on either side as a thin fin or web, varying in extent from about $\frac{1}{4}$ inch to $\frac{1}{8}$ inch.

Fig. 1.



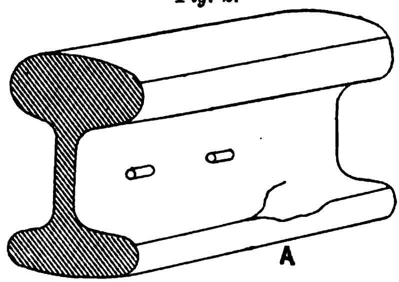
Scale, ½ of full size.

The Author made a careful examination of the wearing face of the portion of the rail received, which was found to be in tolerably good order, though in several places there were noticeable numerous shallow small blowholes and corrosion cavities, which had been rendered visible by the wearing action of the rolling stock. These cavities varied in length and width from about $\frac{5}{16}$ inch downwards, and the depths of five typical ones were—0·055 inch, 0·040 inch, 0·060 inch, 0·002 inch, and 0·060 inch respectively.

The rail-face was, with one exception given below, free from either fine transverse or longitudinal cracks or flaws; its general appearance is shown in Fig. 5, Plate 7. The rail generally was not badly corroded, but the rail-bottom had suffered considerably from corrosion. The part where the rail had lain in the chair was

worn down to the extent of about $\frac{3}{32}$ inch, and was in a rough condition. The appearance presented by the rail-bottom is shown in Fig. 6, Plate 7. About 1 foot from the end there was, on the outside of the bottom flange, a portion of the rail depressed to the extent of $\frac{1}{16}$ inch at point A, *Fig. 2*. On carefully examining the rail along the edge of the overlap or fin on either side of the rail-

Fig. 2.



face, there were found no transverse or other flaws or fissures, with the exception of one longitudinal fissure situated 1 foot from the rail-end and extending for a distance of about $\frac{1}{2}$ inch.

Chemical Examination.—Three separate careful analyses were made from drillings taken respectively from the head, the web, and the bottom of the rail, with the results shown in Table I.

TABLE I.—CHEMICAL ANALYSES OF THE STEEL RAIL.

—	Head.	Web.	Foot.
Combined carbon by colour	0·410	0·420	0·410
Silicon	0·063	0·057	0·062
Manganese	0·778	0·828	0·784
Sulphur	0·115	0·110	0·120
Phosphorus	0·051	0·048	0·048
Iron by difference	98·583	98·537	98·576
	100·000	100·000	100·000

The combined carbon was satisfactory and as high as is desirable for rail-steel, and the silicon, manganese, and phosphorus were present in normal proportions. Sulphur, however, was present in great excess—nearly double the proportion that ought to obtain in a good steel rail. As the carbon and other elements were satisfactory, the excess of sulphur is to some extent responsible for the considerable wearing down noticeable in this rail. Further reference to this point will be made later in the Paper. Except

as regards the sulphur, the chemical analyses show good results, and the rail was free from any extensive segregation of the chemical elements beyond the micro-segregation of the sulphur compounds, referred to in the microscopic part of this investigation.

Physical Examination.—Portions were machined from the head and bottom and submitted to careful physical tests, with the results shown in Table II.

TABLE II.—PHYSICAL TESTS OF THE STEEL RAIL.

——	Distance Between Gauge Points.	Maximum Stress per Square Inch.	Elongation.	Reduction of Area.	Remarks.
	Inches.	Tons.	Per cent.	Per cent.	
Test-piece from rail-head .	2	37·86	27·5	44·0	Silky fibrous.
" " " " bottom	2	38·95	26·5	44·0	Silky fibrous.

The results were satisfactory, the strength being normal and the elongation very good.

High-Power Microscopical Examination at 300 Diameters.—A special section was cut from the rail-face and was carefully polished and etched with very dilute acid to develop the ultimate micro-crystalline structure. This was found to be generally somewhat uneven, so far as regards the distribution and disposition of the carbide-of-iron areas, as these were in places somewhat irregularly massed and variable in size and general structure. In some places, however, there was a moderately good normal interlocking structure, as between the carbide-of-iron areas and the ferrite portions of the steel. The typical normal micro-crystalline structure of this rail, in places free from micro-segregation of the impurities, as seen in longitudinal section near the rail-face, is shown in Fig. 3, Plate 7, from which it will be seen that some of the grey carbide-of-iron areas were of comparatively large size. The sectional area of the rail consisting of ferrite would be about 54 per cent., and the sectional area of the carbide of iron would be about 46 per cent.

Owing to the large excess of sulphur present in this rail, the micro-flaws (apparently chiefly due to sulphide of iron and sulphide of manganese) were found to be very numerous, and in many places they were massed in areas of micro-segregation. The individual sulphur micro-flaws were also mostly of considerable size. A typical illustration of these internal micro-flaws, as seen

in longitudinal section near the rail-face, is given in Fig. 4, Plate 7.

Micrometer measurements were made of some typical internal micro-flaws, the dimensions of which are given in Table III.

TABLE III.—DIMENSIONS OF SOME TYPICAL INTERNAL MICRO-FLAWS IN THE STEEL RAIL.

Longitudinal Dimensions.	Transverse Dimensions.	Longitudinal Dimensions.	Transverse Dimensions.
Inch.	Inch.	Inch.	Inch.
0·0024	0·0006	0·0018	0·0008
0·0012	0·0006	0·0016	0·0006
0·0024	0·0006	0·0016	0·0008
0·0022	0·0006	0·0020	0·0006
0·0020	0·0004	0·0024	0·0004
0·0006	0·0006	0·0020	0·0004
0·0008	0·0008	0·0032	0·0004
0·0034	0·0004	0·0030	0·0008
0·0014	0·0004	0·0032	0·0004
0·0030	0·0004	0·0036	0·0004

These are not the whole of the micro-flaws, but they are representative of those found in this rail.

General Conclusions.—A careful consideration of the results of the foregoing examinations, analyses, and tests, leads to the following conclusions.

1. The rail was worn down by the mechanical abrasion of its work to an abnormal and unusual extent, which indicates either that the rail had been subjected to an excessive amount of work within its limited time-life of 7 years, or that it was deficient in physical endurance. In the latter case, the question arises, to what was this deficiency due?

The rail bore evidence on the wearing-face of having been subjected to very considerable grinding and abrasion, and the manner in which the steel had been beaten or forced out transversely into extensive lateral fins showed that it had done a large amount of work (*Figs. 1*).

Notwithstanding this, the wearing-face was in fairly good order and normal general condition, though there were numerous effects of corrosive action and small blow-hole developments, Fig. 5, Plate 7. At the point where the rail was laid there was a considerable amount of braking and skidding of wheels. An approximate estimate of the traffic which had passed over the rail was kindly furnished by the chief engineer of the line, from which it would appear that a total weight of about 48 million tons had

passed over the line during the life of this rail, so that this single rail may be considered to have carried a total weight represented by 24 million tons.

The loss in the mass of the rail from corrosion on the web and bottom is very noticeable on comparing *Figs. 1*, and Figs. 5 and 6, Plate 7. The corrosion is often more excessive in tunnels than in the open air. The under surface of the rail-bottom, where it had rested in the chair, was much weakened by extensive transverse depressions and corrosion-cavities, though there were no actual fissures. These transverse depressions, or indentations, resulted from mechanical wear and the cold hammering which the rail had received in the chair, caused by the rolling stock passing over it. Another feature manifested in the bottom surface of this rail was the considerable extent to which the bottom of the rail, where it had rested in the chair, had been widened by mechanical shocks and the vertical pressure from passing trains. This is illustrated in Fig. 6, Plate 7.

2. The chemical analyses show that the general composition of the steel was excellent, the chemical elements being well balanced, with the exception of the sulphur, which latter constituent was present in considerable excess—nearly twice as much as ought to be present in a good rail-steel. The combined carbon was normal, and in a proportion calculated to promote both the durability and safety of the rail in service. The extensive wearing down of this rail is not, therefore, traceable to deficiency of carbon, but, in the Author's opinion, it is due principally to the heavy amount of work put upon the rail, the normal wearing action being considerably intensified by the injurious physical effects arising from the micro-segregation of the sulphide of iron and the sulphide of manganese, to which allusion has been made in the account of the microscopical investigation.

3. The physical examination shows that the steel in the mass was of generally satisfactory quality.

4. The high-power microscopical examination, in conjunction with the chemical analyses, shows that the weak point in this rail was due to the excess of sulphur present.

This impurity, being present in such excess, had micro-segregated (as sulphide of iron and sulphide of manganese) as shown in the high-power micrograph, Fig. 4, Plate 7. The presence of these innumerable minute areas of segregation had greatly facilitated (for mechanico-physical reasons easily understood) the disintegration and wearing down of the rail, under stress of wear, though the distribution of these sulphide micro-flaws throughout the mass of

the steel was such as not to materially affect the physical strength of the rail as a mass, as shown by the tensile tests in Table II. Moreover, the normal crystallization of the carbide of iron and ferrite had also evidently been to some extent disturbed by the presence of the numerous micro-segregations of the sulphide of iron, allusion to which is made in the account of the microscopical examination of the rail.

The microscope detected and visibly demonstrated some of the minute causes of internal weakness leading to the disintegration of this rail, confirmation being afforded by the result of the chemical analyses.

5. It is not generally desirable that rails should be allowed to wear down to the same extent as this one before being removed from the main-line service. On comparing the original section with the worn section (*Figs. 1*), it will be seen to how large an extent the strength of the rail had been reduced by mechanical wear, abrasion and corrosion; this being represented by a reduction in weight from 84 lbs. per yard to about 64½ lbs. per yard, which approximates to a total reduction in weight of 30 per cent., indicating a corresponding reduction in strength.

The Author thinks it would be desirable also to have a heavier rail, weighing about 95 lbs. per yard, of a suitable section to meet the increased traffic and the weight of modern engines and rolling stock, and it is especially desirable to use heavier sections in tunnels.

6. In the Author's opinion, judging from the results of numerous investigations of rails of known conditions of long service which he has recently made, a medium carbon and medium manganese rail, keeping the impurities, such as silicon, sulphur and phosphorus, within the lowest limits (as recommended in his recent chemical and physical specification for steel rails)[1] will be found the safest and most durable for traffic of the kind to which the rail referred to in this Paper has been subjected. To ensure that a reliable composition and structure of rail is obtained, it is of advantage for railway companies to have their new finished rails (apart from the maker's test of the ingot) chemically and physically tested.

It has been seen that the corrosion of the steel rail in the tunnel

[1] The extensive chemical and physical investigations the Author has for some time past been making on steel rails for some of the chief railways in England have shown the best proportions of carbon, manganese, and other elements, productive of a safe and durable rail. Further information on the fatigue deterioration of steel rails, outside tunnels, is contained in a series of Papers published by him in *Engineering*, during the years 1897 and 1898.

has been at the average rate of 2·8 lbs. per yard per annum, which is largely in excess of the normal wear outside tunnels. Elsewhere it has been observed that the flange of a Vignoles rail corroded in various places to the extent of 0·086 inch within 2½ years, and in other situations rails have been known to corrode as much as 0·260 inch within 3½ years.

A corrosion as high as 0·390 inch has been observed on the underside of a rail-flange, with a maximum wear in the head of 0·490 inch, within a period of 11½ years. This excessive wear in tunnels may be obviated by employing heavier general sections with a wider wearing-face, and by special selection of rails of a chemical composition and physical structure best adapted for wear in such a situation. Longitudinal sleepers and heavy-sectioned flat-bottom rails may be used with advantage. With transverse sleepers it is desirable to increase the number of sleepers per yard.

In Table IV the Author gives for purposes of comparison the approximate loss in weight, in pounds per yard per annum, of a number of rails he has examined, which have endured the heavy wear of main-line traffic in the open air to a similar extent to that

TABLE IV.—AVERAGE LOSS IN WEIGHT PER ANNUM OF ELEVEN RAILS OF KNOWN AGE AND CONDITIONS OF MAIN-LINE SERVICE.

Time-Life.	Average Loss in Weight per Annum.
Years.	Lbs. per Yard.
22	0·260
24	0·310
23	0·130
23	0·130
21	0·480
25	0·420
17	0·320
18	0·280
18	0·280
19	0·630
Average 21	0·324
7[1]	2·800

of the rail referred to above. From this it will be seen that the effect of the tunnel has been to increase the wear of the rail from an average of say 0·324 lb. per yard per annum to the high

[1] This rail had been laid in a tunnel during the whole of its life. The other ten rails had been in the open.

average of 2·8 lbs. per yard per annum. The rails were selected at various places over a length of about 200 miles of main line.

The Author considers as a general rule that rails in tunnels should only be allowed to remain in the permanent way for one-half (or in some cases only one-third) the time that is usually allowed for their ordinary use outside tunnels; thus if 14 years may be regarded as the life of a rail under ordinary circumstances, 7 years may be regarded as the maximum life allowed in average tunnels, consistent with safety. This conclusion is of course open to exceptions, according to varied circumstances. In special instances rails in tunnels ought to be taken out after a less period of wear than suggested above, and there are tunnels in which rails ought not to be retained in the permanent way for a longer period than 3 years or 4 years.

These matters, however, will vary according to the nature of the tunnel and the extent and character of the traffic imposed on the rail, so that it is not easy to make a general rule.

The Paper is accompanied by four drawings and two photographs, from which Plate 7 and the Figures in the text have been prepared.

Discussion.

Sir DOUGLAS FOX, President, said that the members had listened with great interest to the Paper, partly historical and partly practical, which had been placed before the Institution. They were very pleased to see Sir Lowthian Bell there that evening, and felt that he had made a valuable contribution to the "Proceedings" of the Institution, as he had been closely connected with the matters dealt with in his Paper, from the early days of railways. The members, therefore, not only had a little insight into the inner history of the subject, but also had the opinions of a gentleman whose experience was as large as that of anyone else upon the very important matter of the manufacture and use of rails. He proposed a very hearty vote of thanks to Sir Lowthian Bell for his Paper. Sir Douglas Fox.

With regard to Mr. Andrews' Paper, the members would agree with him that it was a valuable contribution to experimental research in connection with the qualities of steel rails, and he begged to move a vote of thanks to the Author for his communication.

Sir WILLIAM ROBERTS-AUSTEN, K.C.B., in view of the fact of so many wishing to take part in the discussion, would pass over the historical part of the Paper, which Sir Lowthian Bell's vast experience and great knowledge had enabled him to deal so effectively with, merely thanking him for that contribution to the history of metallurgy. He would like to ask a question with reference to the rate of wear in the case of iron and steel respectively. How much did Sir Lowthian think was due to attrition, and how much to oxidation and corrosion in such cases? Might it not be in the case of steel, which contained carbide and ferrite, that the carbide and ferrite set up an electric couple, which promoted corrosion in the case of steel as compared with iron, and hence the wear was greater? Then again, with reference to the question of turning rails, he had recently examined a great number of worn rails with the microscope, and he found that very many of them had incipient flaws. He considered that it was a highly dangerous practice to turn a rail, but he was bound to say that he had had no practical experience of the wear of rails on a road. Sir Lowthian had referred to the change of structure in rails after prolonged use. He thought Sir Lowthian had in view Sir William Roberts-Austen.

Sir William Roberts-Austen. the mysterious appearance of martensite in the St. Neot's rail, which was thought to be due to a molecular change during the use of that rail. The appearance of that martensite had not as yet been absolutely and satisfactorily explained, for although the result had been closely imitated, the conditions were hardly such as could have obtained in the actual use of the rail on the road. With regard to the point in Mr. Andrews' Paper as to the wear of rails in dry tunnels as compared with that in wet tunnels, it seemed to be an interesting suggestion that the water in wet and in badly ventilated tunnels might absorb the corroding gases, and in that way take them out of the sphere of mischief. Without suggesting that Mr. Andrews' drawings were not absolutely faithful, he wished he could induce him to come over to the side of those who discarded drawing and employed photography with so much success in the examination of steel and of alloys generally.

Mr. Inglis. Mr. J. C. INGLIS remembered with pleasure discussing the question raised in the Papers on a previous occasion, when Sir Lowthian promised the Paper to which the members had now had the pleasure of listening. He then expressed his feeling that the greater the number of cases to be dealt with, the more perplexing, apparently, the problem became. But he thought he might fairly say that one point seemed to crop up now and again from the chaos, viz., that in making steel rails, cleanliness in keeping the rails free from scoriæ and other extraneous matter seemed to be the most important point in obtaining uniformity of strength, even in Bessemer steel. He had had to examine, with the assistance of those who advised him, a large number of cases of fractured rails, where, on testing, the behaviour of the steel on both sides of the fracture was found to be entirely satisfactory. Fracture in such cases could only be explained as the result of an incipient flaw. Occasionally there were indications of such a cause; in other cases no indications were found and the cause was assumed. At any rate there was some such cause, which largely detracted from the credit fairly due to Bessemer steel if manufactured with greater attention to the exclusion of foreign matter. He only said that in passing, as it appeared to him to be some little explanation of many of the difficulties which had to be faced in accounting for failures of steel rails. Sir William Roberts-Austen had spoken of the difference in wear of iron rails as compared with steel rails. He had ventured to make a similar suggestion some time ago, and was rather severely handled for doing so. He had said then that under moderate traffic an iron rail would last quite as long as a steel rail, and that he thought the extra wear

was due, as Sir William Roberts-Austen had suggested, to the fact that, for some reason or other, oxidation was more rapid in steel than in iron. It was well known to those who built dock-gates that it was always wise to have iron plates and not steel plates, and that was a little indication of how the wind blew in that matter. Then there was the question of attrition. Steel rails undoubtedly seemed to pulverise, if he might use that term, in a way which iron rails did not. That was really the only explanation he could give of it. He quite agreed with Sir Lowthian Bell's remarks as to the Siemens-Martin process, although his experience was small as compared with the Author's. But having made a good many experiments, both practically and in the laboratory, he had no doubt of the superiority of that steel. At present the Great Western Railway Company were using it for fittings, and he had not the slightest hesitation in saying that if ever the price of that kind of steel approached the price of Bessemer steel, there would be no hesitation in using it more frequently. By its use a more reliable rail would be obtained, doubtless on account of the longer time which was occupied in its manufacture, so that there was greater power of eliminating defects. An experiment which he had introduced proved that the rail was at once tougher and stiffer than a Bessemer rail, and the fact that the Great Western Railway felt it was quite worth while using a particular sort of steel in fittings—subjected, of course, to a great deal more wear and tear than an ordinary rail—showed that that statement was correct. He noticed with a certain amount of satisfaction the observation in the Paper that at a certain station near Penrith there had been a great many breakages at one place, which had been explained as being due to a heavy fall of snow. He believed that a good many breakages of rails arose from movement of the sleepers—the very cause which was found in that particular instance. Engineers often talked learnedly about the quality of the steel when the fault was in fact inefficiency in maintenance, and he believed that particular cause of fractures would increase instead of decrease as manufacturers went on making rails heavier; at any rate, he felt sure it would so far as the joints were concerned, because the more unbending and rigid the structure became, the more likely it was, if there was a deflection in the rail, to get at certain points very severe twists and reciprocating stresses which would produce fracture. It would appear from Sir Lowthian Bell's Paper that the Board of Trade now absolutely refused to certify a new line for passenger traffic if that line was laid with rails which had been in use in other parts of the line. He hoped the Board of

Mr. Inglis.

Mr. Inglis. Trade would never get to that advanced stage of consideration for public safety. He thought if they did they would be somewhat illogical. At any rate, he would be a sinner in the matter, if the Board of Trade took it into consideration. His Company were now making a railway for passenger traffic and goods traffic—it was true it was a light railway—and there the Board of Trade had inserted a clause in the Bill providing that worn rails might be used if they were not lighter than 60 lbs. per yard when laid. That was an indication of what the views of the Board of Trade might be about light railways; but he did not think such a regulation as that mentioned by Sir Lowthian Bell would be quite fair. He had a case now, for instance, where, on the main line, with very heavy traffic, the spacing of the sleepers was perhaps wider than he would like it to be. The ballast was not quite satisfactory, and would have to be taken up, and the sleepers required to be re-spaced. The rails were 7 years old, and were almost at their best, or, at any rate, in quite good working-order. A railway company might desire to put down a type of road which was adjacent, and might take up those perfectly good rails and the sleepers, and move them to another line less frequented and carrying lighter traffic than the main line; and if the Board of Trade prevented such an operation as that, he thought they would only perpetuate the jolting of the British public in express trains; because, if the Board of Trade would not allow it, the simple result would be that the company would have either to leave the rails until they were considerably more worn, and so perpetuate the unsatisfactory running for a series of years, or to take up the whole at a greater cost, re-space the sleepers, shift their old beds, and produce an unsatisfactory road—at any rate, for the first 12 months after it was laid. He thought the Board of Trade ought not to be encouraged in any such very safe method as was suggested in the Paper.

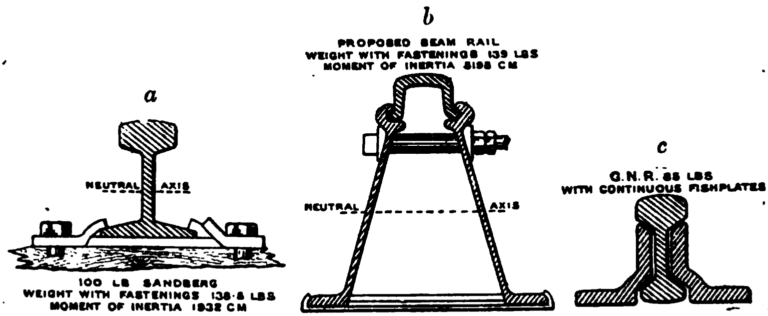
With regard to the second Paper, he had had some very careful observations made on the rails taken from the Box Tunnel, where there was excessive wear. He compared carefully a section of the rail as it was taken out with the original section, and in the case of maximum wear it appeared that just about half the loss was due to oxidation, and the other half due to attrition, or the wearing away at the top. In the majority of the instances there was more loss from wear than from oxidation, but there were one or two cases in which the one approached the other. He felt convinced that in most tunnels, especially in certain cases where the tunnels were not moist but badly ventilated, a greater wear occurred on the top of the rail than was the case in rails outside;

because, apparently, when trains had passed over, the top surface was left bright, the deleterious gases were able to attack it, and there was a certain amount of oxide formed which was removed by the next train that came along. The process of wearing down the top of the rail was thus considerably expedited. He believed the determining factor in the wear of rails in tunnels was the ventilation—and by ventilation he meant the introduction of fresh air, and the removal, as far as possible, of moist air. But in the Severn Tunnel, for instance, assuming a train was running from Cardiff, it ran down into the tunnel on a gradient of 1 in 90, and came up on the other side on 1 in 100. In 32-foot rails put down in the sleeper-road 6 years ago, the wear on an 86-lb. rail in 6 years at the Welsh end of the tunnel was 1·69 lbs. per yard; 10 chains farther on the wear on a similar rail was 3·94 lbs. per yard; 10 chains farther on 7·51 lbs. per yard; and 10 chains farther on, or 30 chains from the face, it was 10·22 lbs. per yard, showing a steady progression of the rate of wear of the rail on entering the tunnel, where of course the ventilation was not so good, or where the passage of the gases over that particular part was greater. He had not calculated the wear per yard per annum, but it could be obtained exactly from the figures. At the east end of the tunnel, coming up the 1 in 100 gradient to come out of the tunnel, at 32 chains from that end, with rails of the same weight—86 lbs.—which had been laid 6 years, there was a loss of 11·63 lbs. per yard; 10 chains nearer to the mouth it was 10·69 lbs. per yard; 10 chains nearer again, for some reason or other, it was 11·63 lbs. per yard; and at the mouth it was 6·38 lbs. per yard, showing, as suggested, like the first series he had given, that there was the same tendency to increased wear as a less well-ventilated part of the tunnel was approached. The trains ran down without steam in the first place, and came up at the other side with all the steam on that could possibly be obtained, perhaps also letting down a little sand. Mr. Inglis.

Mr. T. G. Gribble remarked, in reference to the deflection-trials mentioned in Sir Lowthian Bell's Paper, that it was not stated whether the deflection was that of the rail-joint, or of the adjacent section between chair-supports, or of the whole rail. The deflections stated, if occurring at the rail-joint or between any two sleepers, would seem to indicate impossible fibre-stresses in the rail. In some rather crude experiments on deflection he had made, with a pair of folding wedges on which the travel measured the deflection, he had obtained results which, although very different from those in the Paper, indicated much severer stress than was Mr. Gribble.

Mr. Gribble. ever worked to in bridge-structures, or, indeed, than was allowed by the Board of Trade. The rail was an 85-lb. bullhead, and the load was a 16-ton pair of driving wheels at a standstill. The joint was tried both fished with ordinary fish-plates, and also with the fish-plates removed. The general conclusions arrived at were as follows:—1. That the stresses on the extreme fibre of the rail were from 3 to 5 times as great as the stresses worked to in bridges. 2. That the joint with ordinary fish-plates was statically much weaker than the rest of the rail, apart from wear and tear due to hammering, etc. 3. That the fish-plates did not prevent the rails at a joint from acting almost entirely as a pair of cantilevers. 4. That the adjacent sections of the rail between chair-supports did not act as portions of a continuous girder but as if they were supported beams, probably because a very slight settlement in the sleepers was sufficient to alter the reactions.

Figs. 1.



To illustrate how far the heaviest and stiffest rail in use, the Sandberg 100-lb. rail, with steel bearing plates, *Figs. 1, a,* was from coming up to Board-of-Trade requirements for structural steel, he had formed the same material into an attenuated A beam with removable rail-head, shown in *Figs. 1, b,* so as to reduce the flange-stress to 6½ tons per square inch. If, therefore, rails were to be brought up to the standard which was considered none too safe for bridge-structures, let alone hammering, attrition, and corrosion, which were much more aggravated in rails than in bridges, it was plain that they would have to be radically altered. Whatever might be the relative imperfections of the Bessemer process as compared with the Siemens-Martin process, it was not clear to his mind that rail-fractures were as much due to that cause as to the fact that the rails were structurally weak. The illustration of a Bessemer rail given in Mr. Andrews' Paper seemed to bear

strongly in favour of the tenacity and ductility of that particular rail, in spite of its tremendous punishment. Until much heavier rails could be afforded the principal point to strengthen was of course the joint. *Figs. 1, c*, showed the continuous fish-plate used on the Midland and Great Northern bridges where the road was "tied." The weight was doubled, but the combined moment of inertia was about 1½ times that of the rail. This continuous fish-plate had been used also in shorter lengths to bridge a pair of sleepers, and formed a very safe joint. Mr. Gribble.

Mr. J. A. McDonald could hardly agree with the conclusion drawn in the Paper on the question of the life of iron rails as compared with steel. Whenever he had had the opportunity of judging between iron and steel in similar circumstances over sufficiently long periods, the result, with one exception, had always been in favour of steel. That exception was in the West of England, where an old iron road was laid on an extremely soft formation, making the road very elastic, and it lasted about 28 or 29 years. Everywhere else his experience had been that, where sufficient time had elapsed to enable a judgment to be formed, steel rails had stood better than iron. He remembered one case in particular, in Derbyshire, which showed, he thought, a reason for the iron rails fracturing so quickly. It was on magnesian limestone rock formation, and at the end of 16 years the rails broke in the most unaccountable way. When they were examined it was seen that the fractures showed like very bad pig-iron, somewhat similar to cinder pig-iron, and he believed this was due to the extremely hard formation on which the rails were laid. With regard to wet and dry tunnels, he had had a great deal of trouble, as all engineers had, with rails wearing out in tunnels; but, without any exception, the worst tunnels had been the wet ones. He could mention half-a-dozen notable instances where the tunnel was over a mile long, and in the wet portion of the tunnel the rails had lasted only 3½, 4½, or 5 years, while the rails in the dry portion had lasted nearly double that time. He thought the rapid wear of the rails in those tunnels was due not so much to the actual wear on the face of the rail as to the corrosion all round. Some 8 or 9 years ago Mr. Francis Stevenson of the London and North Western Railway had tried the experiment of painting his rails. Mr. Stevenson had been kind enough to show him what he had done and the result, and about 6 years ago he had adopted the same system, and now he was painting the rails in all tunnels that were at all wet or more than half-a-mile long. He painted them with four coats, three before they were put in and one after they were in the road, the paint used being red lead and boiled oil without Mr. McDonald.

Mr. McDonald. anything added to it. Where the rails had been in long enough to judge, he had found this practice to result in lengthening their life by between 30 and 50 per cent. He had one case where the rails were in good order, and they had now been in longer than the rails which had been in the tunnel previously. He quite agreed with Mr. Inglis in hoping that the Board of Trade would not make a mistake with regard to prohibiting the use of worn rails, for light railways in particular. Of course it was known that the Board of Trade "had never made a mistake," and he hoped they would not make a mistake in that instance. The practice was a means of providing, at rather less cost, a very much stronger road than would be provided in any other way. He had a light railway in mind at the present moment, where between 8 and 10 miles of road were required, and the engineer who was constructing it had asked him to supply worn 85-lb. rails. The Midland Railway Company, of course, did not wear the rails down to the same extent as those mentioned by Mr. Andrews. In his experience, 85-lb. rails in the ordinary main line came out when they weighed about 76 lbs., and rails of such weight that were originally 85 lbs. were very much better than the ordinary 60-lb. rail which would be used for a light railway.

Sir Benjamin Baker. Sir BENJAMIN BAKER, K.C.M.G., Past-President, thought he might reassure his friends Mr. McDonald and Mr. Inglis on the point which had been raised about the views of the Board of Trade on the question of using old rails. One of the first remarks that he had made when he was on the Light Railway Commission of the Board of Trade was to protest against what might be called the definition of a light railway as a railway which had a certain limited weight on the driving-wheel or which had light rails. He said if there was to be any extensive introduction of light railways it could only be through the help and assistance of the leading railway companies, and questions of economy would be the first consideration. Therefore, one of the very first conditions would be that the railway companies should be able to take out their old rails and use them for light railways, and should be able to take their old rolling stock and engines which were obsolete for main-line service and put them on light railways. There was not a word of protest from any of the Board-of-Trade officers present, and he did not think any fear need be felt about putting the old rails of main lines on light railways. It would be regarded as a common-sense matter which all Englishmen, including the Board of Trade, would accept as proper. He was certainly not going to criticise in any way the Paper of his dear old friend, Sir Isaac Lowthian Bell. From his very earliest days of pupilage he had

Sir Benjamin Baker.

been accustomed to look up to Sir Lowthian with the same amount of respect that he looked round at the names of Cort, Rumford, Bramah, and others on the walls of the Institution. His earliest associations with the blast furnace and with the chemistry connected with it had been linked with Sir Isaac Lowthian Bell, and it was really not only with personal feeling, but with the more general feeling shared in by every member of the Institution of Civil Engineers, that he was delighted to see Sir Lowthian sitting there that evening after the many years' service he had rendered to practical science. It was wonderful, he thought, that, after Sir Lowthian had passed his fourscore years, he was taking the same keen interest in the engineering profession that he did in his earlier days. He had said before that in the Institution of Civil Engineers the old members were beloved, and there was no one, he was sure, who was appreciated more than his old friend, Sir Lowthian Bell.

Mr. Johnson.

Mr. Richard Johnson was very glad to find that the Board of Trade objected to turning rails. That objection had been sustained, as might be remembered, by a very bad illustration of the effects of turning rails between Tunbridge Wells and Tunbridge. He was very glad to know that that practice had been stopped. Sir Lowthian Bell had mentioned the fact of rails being turned upon the North Eastern Railway, but there Mr. Thomas Elliot Harrison had adopted a cushion, and that helped very much to save the rail before it was turned. He thought Mr. Copperthwaite had continued the practice until he had put into work the bull-headed rail. He was very glad to learn from Mr. McDonald that he had adopted a plan of painting the rails in tunnels, and he believed it would be found very successful.

Mr. Robertson.

Mr. F. E. Robertson wished to ask one question on which Sir Lowthian Bell's opinion would be valuable. There was an impression abroad, which was found reflected in the American journals, that steel rails as made within the last few years were much softer than they used to be, that they showed signs of wear and wore out sooner, especially at points and crossings. Where there was so much smoke there was probably some fire, but he did not know that the fact of the rails being softer had ever been established. He had asked some of the men in India who complained of the rails being too soft to send samples home so that experiments might be made to test their physical hardness. Assuming that they were softer, it was scarcely probable that rails made under the same inspection and to the same specification were softer on chemical grounds, and the reason was there-

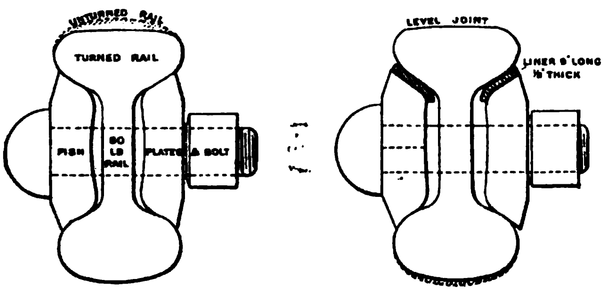
Mr. Robertson. fore to be sought in the process of manufacture. There was no question, he believed, that in former days the ingots were much more gently treated, and the rails were rolled more easily and finished at a much lower temperature. Nowadays an ingot was stripped as soon as it could stand upright, it was hauled off to the soaking pits, and it went through the rolls and was turned into a rail at as high a temperature as it could stand at. What he would like to ask Sir Lowthian Bell was, whether it was not possible that the great speed at which the work was done now, and the higher temperature throughout under which the rails were finished, might be the cause of their softness at the present day?

Sir Lowthian Bell. Sir LOWTHIAN BELL, Bart., in reply, observed he had brought some illustrations of the various stages of making iron, which were on the table and which members might be interested in looking at after the meeting. With regard to the turning of rails, a statement had been made about a plan introduced by Mr. Harrison of having a cushion under the rails, and no doubt that was a most useful addition. A cushion was laid under the rail between it and the chair. But, in addition to that, steel liners were now used so as to bring the top of the rail exactly on a level with the tops of the adjoining rails. The plan adopted was illustrated in *Figs. 2.* As regarded the length of the line upon which that trial was made, namely, between York and Darlington, probably the busiest part of the North Eastern system, there were nearly 1,000 tons of rails which had been turned, against something like 3,000 or 4,000 tons of rails which had not been turned, and on weighing those rails there was absolutely no difference whatever in loss of weight. The turned
sails were lasting as well as those which had not been turned.
it cou. regard to the regulations of the Board of Trade, he quite
railway vith Sir Benjamin Baker as to the futility of such a
consideratiınduct as that mentioned, yet he might state his
be that the race. The company with which he was associated
rails and use thValley line, running up to the neighbourhood of
their old rolling ıen approaching the lofty hills of Austin Moor.
line service and por found that the line was being laid with
word of protest from removed from very severe portions of the
and he did not think e said: "I object to this. As it is done I
rails of main lines on ıt I will never pass any more lines which
common-sense matter wl rails." As a matter of fact there was a
of Trade, would accept th Eastern Railway Company were now
criticise in any way thorks of Messrs. Bolckow, Vaughan & Co.
Lowthian Bell. From -

Sir Lowthian Bell.

and their cottages, where the line ended; and they were prevented from laying down old rails upon that portion, with the result that it was being laid with new rails. With regard to deflection, in the diagram given in the Paper (*Fig. 5*) the curve represented the deflection caused by the engine and tender of a train running from right to left. It would be observed that there was a well-defined point, and he reckoned that going at the rate of 45 miles an hour, which was a long way short of the regular speed for express trains—practically 60 miles an hour—the engine went over the point of greatest pressure in an inconceivably small fraction of a second, and therefore the cumulative vibration spoken of by Sir Andrew Noble could not be said to have much effect on the general conduct of the rail itself. The diagram would be seen to be irregular, oscillating slightly according to the nature and work of the engine itself. The locomotive could not be balanced so exactly as not to cause a slight blow, and

Figs. 2.



consequently the lines on the diagram were in a sort of saw-toothed form, until the whole of the heavy part of the train, *i.e.*, the engine and tender, had passed the indicator, when the carriages alone could affect the readings of the instrument. With regard to the rusting of rails, it was a well-known fact, and he had never heard it disputed, that if an iron rail was laid down alongside a running rail, the oxidation of the unused rail was much greater than that of the rail in use. Cases had occurred where rails had been overlooked and left for many years, and the amount of corrosion of those rails, which had never been used at all, was very great. He remembered quite well that when it was first proposed to lay rails of malleable iron the objection raised was that malleable iron corroded much more rapidly than did cast iron. Referring to the action on rails in tunnels, and in fact near any centre where the atmosphere was polluted by chemical fumes, he might mention that the rails and the telegraph lines

Sir Lowthian Bell. near the chemical works in the neighbourhood of Newcastle, for instance, were very much corroded, and rails were taken out of a tunnel near Leeds, where in 7 years they had lost 21 lbs. per yard in weight. He was very glad to hear that the extreme corrosion of rails in tunnels could be stopped by painting them, and he would carry away from the meeting an impression which would induce him to try that plan. He would like to say one word on the subject of the two processes of making rails, the open-hearth and the Bessemer. In the latter process something like 15 tons or 20 tons of metal was run into the converter, and in less than as many minutes it was converted into steel. It was idle therefore to talk of making any examination of the condition of the contents of the ingots where the time was so short; whereas with the open-hearth furnace a very different state of things prevailed. Practically it might be said that the charge was in the open-hearth furnace for nearly 10 hours, and the practice was to take out a certain quantity of steel, beat it under the hammer into a flat plate and then bend it. It was then a circular plate, and was bent a second time when cold. Unless it stood that test without breaking, the product would be rejected. The workmen by experience could read the lesson that was taught them, and there was opportunity in the open-hearth process, from the length of time during which the operation lasted, to introduce modifications. If the product was deficient in carbon, carbon could be added, or if it was too high in carbon or sulphur, those things could be corrected in the furnace itself before the product was run into the ingot moulds and formed into steel. He was hopeful that the day would come when, in order to secure a rail of uniform quality and of the highest possible strength, railway engineers would specify that all rails should be made in the open-hearth furnace.

Mr. Andrews. Mr. Thomas Andrews said he had greatly enjoyed Sir Lowthian Bell's Paper both from its retrospective character and from its bringing one into touch with things of the past and with modern requirements. One part of the Paper especially struck him as being important, namely, the different deflection and strength of rails taken from various parts of the same ingot. He thought there was a danger at the present time of cutting too little from the top of the ingots from which modern rails were made. There was a considerable amount of impurity always located in the top part of an ingot, and if sufficient was not cut off there was a liability of the rail which represented the top of the ingot being in a somewhat brittle and dangerous state. With regard to Sir W. Roberts-Austen's remarks, he was not at all prejudiced in favour of drawings in preference to photography in microscopical work, but

believed in the use of both, some for one purpose and some for another. He hoped to show specimens of each. Mr. Andrews.

Mr. Andrews subsequently exhibited a series of lantern slides showing the chemical composition of steel rails and fractures and flaws in rails.

Correspondence.

Mr. W. L. JORDAN observed that Sir Lowthian Bell had given a clear explanation of the manner in which a fast train might run in safety over a fractured rail which could not carry the same train if moving slowly; he presumed, however, that it was nevertheless generally recognised that the vibration caused by a fast train might break rails, or shake to pieces girders, which would not be injured by the passage of the same train moving slowly. He alluded to this for the purpose of suggesting that Sir Lowthian Bell might perhaps be able to add some further information to the interesting statement he gave regarding the relative number of rails broken on different parts of the North Eastern line. A point of special interest in connection with the subject seemed to him to be as to whether the same rule for spacing sleepers prevailed all over the Company's lines, or whether any particular rule for spacing prevailed in the areas in which breakages were most numerous. Mr. Jordan.

Mr. J. E. STEAD considered it a great triumph in metallurgical research when Professor Arnold proved that the sulphur in steel, or at least the greater part of it, separated out in combination with iron or manganese, and did not remain in combination with the mass of the steel in the way phosphorus did, but was thrown out of solution and appeared as envelopes to the crystalline grains of steel under certain conditions. Mr. Stead had noticed they were more usually in the form of minute globules in large ingots. When the steel ingots were rolled out into rails, these globules were elongated and appeared in longitudinal section as lenticular forms; but in reality, as he had shown in a Paper[1] on the causes which tended to produce fracture in iron and steel, they were of torpedo or cigar shape. When the original section of the ingots was greatly reduced, these sulphide globules were rolled out and became elongated threads. He had observed that they Mr. Stead.

[1] Proceedings of the Cleveland Institution of Engineers, 1898-99, p. 12.

Mr. Stead. were usually quite separated one from the other. From an engineer's point of view, they were not more harmful than cinder or any other non-metallic foreign matter. When this discovery was clearly established, it came as a great relief to his mind, for now it was proved that the sulphides were only mechanically mixed and were not chemically combined with the cold steel.

He would like to ask Mr. Andrews if he considered that he had clearly and logically proved that the separated sulphides were responsible, in any way, for the wear of the rail he examined. It appeared to Mr. Stead that, to have proved this point, a companion rail, identical in composition with the rail in question (excepting as regards the sulphur which should have been say 0·06 per cent.) should have been subjected to the same conditions of treatment, the wear of each being noted. It was stated that the rail had "been subjected to very considerable grinding and abrasion," and the manner in which the steel had been beaten, or forced out transversely into extensive lateral fins showed that it had borne a large amount of work. It was also stated that the physical properties were highly satisfactory, and judging from the fact that the elongation was 27 per cent., and the reduction of area on pulling it asunder was 44 per cent., he quite agreed with Mr. Andrews that it was excellent steel. Was not this strong evidence that the separated sulphides could certainly not be considered as "germs of disease," or "flaws," tending to cause disintegration during vibratory stresses, or excessive wear during crushing forces?

At the conclusion of Mr. Andrews' remarks, speaking of rails generally and not, presumably, of rails high in sulphur, he said, "There are tunnels in which rails ought not to be retained in the permanent way for a longer period than 3 years or 4 years"; clearly showing that it was his opinion that under certain conditions average rails in tunnels would wear much more rapidly than the example brought forward, which had done good service, and had, according to Mr. Andrews, enjoyed the maximum life allowed of 7 years.

It appeared to Mr. Stead that Mr. Andrews' results would tend to remove from engineers' minds the lurking fear that sulphur was a great evil in structural material, for here was an excellent rail with 0·12 per cent. of sulphur in it, which had been subjected to the worst possible conditions and treatment, yet it came through the ordeal triumphantly, and did not show any deterioration in its mass after 7 years' percussive and vibratory stresses. On examining the Table giving the dimensions of the so-called sulphur flaws, it would be seen that not one of them was longer

than 0·0036 inch, and the average was certainly much less. They appeared great when magnified 300 diameters, but in reality they were exceedingly minute. If the whole of the sulphur in the rail was in combination with manganese the actual weight would be 0·31 per cent. He thought that if Mr. Andrews would look at the question from this point of view, he would scarcely conclude that an excess of 0·15 per cent. of sulphides, which was equivalent to cinder, would be responsible for the rapid wearing of the steel rail. Mr. Stead.

Sulphur, in excess, usually made steel redshort, and rails unfit to send out of the maker's works. Manufacturers, in their own interest, aimed at keeping that element within limits, and with such success that during the last few years they had greatly reduced the proportion of wasters by adopting methods of keeping the sulphur down. Mr. Stead's experience was that, provided the rails were sound and were free from visible flaws, about 0·1 per cent. sulphur did not appear to cause rapid wear or produce fracture, and he did not think Mr. Andrews had proved the reverse to be the case.

Sir LOWTHIAN BELL, in reply to the Correspondence, gave the following particulars of rails found broken on the system of the North Eastern Railway Company, which he had abstracted from information communicated to the Board of Trade Committee on Rails. Sir Lowthian Bell.

The percentages of phosphorus in the two following Tables being, in some cases, lower than usual, he had added two series of analyses, being eight specimens from the North Eastern line and eight from the Lancashire and Yorkshire. In both of these the analyses had been made by Professor Thorpe in the laboratory of the Board of Trade. The tests of strength had been made in the presence of certain members of the Rails Committee appointed by the Board of Trade, the late Major Marindin, Government Inspector, being of the number.

The rails had been classified, beginning with those withstanding the highest aggregate fall of the weight; the absence of any correspondence between the composition of the specimens and the force required for fracture was too noticeable to require further comment. Professor Thorpe had had made a special examination of these specimens, and in explaining the consistency of a high percentage of phosphorus with superior strength, he considered that this element might exist in a rail under two distinct forms, one of which conferred brittleness, while the other was harmless in this respect. In the event of further investigation confirming this view a question of importance would follow, viz., was there

Sir Lowthian Bell.

RESULTS OF TESTS AND ANALYSES OF TWENTY-SIX STEEL RAILS BROKE UNDER 5 FEET OF FALL OR LESS. WEIGHT

Feet of fall .	0·5	0·5	0·5	0·5	0·5	0·5	1·75	1·75	1·75	1·75	1·75	2·0
Composition—												
Phosphorus	0·09	0·08	0·053	0·014	0·082	0·07	0·02	0·08	0·07	0·03	0·05	0·49
Carbon .	0·50	0·42	0·42	0·53	0·35	0·39	0·61	0·58	0·45	0·30	0·30	0·48
Sulphur .	0·14	0·09	0·04	0·11	0·12	0·08	0·02	0·12	0·12	0·10	0·11	0·13
Silicon .	0·05	0·08	0·103	0·051	0·06	0·11	0·06	0·07	0·15	0·08	0·08	0·07
Manganese	0·68	0·75	0·80	0·59	0·56	0·72	1·34	0·53	0·98	0·49	0·49	0·60
Totals .	1·46	1·42	1·416	1·295	1·202	1·37	2·05	1·38	1·77	1·00	1·03	1·77
Years in use.	19	19	10·16	17·33	23·58	19	17	20	15·75	16·75	16·75	19
Loss per yard lbs.	3·13	4·75	12·20	4·63	9·38	6·25	5·13	5·63	10	14·12	12·12	2·75
Worn head .	down	down	down	up	down	up	up	up	up	up	up	down

RESULTS OF TESTS AND ANALYSES OF TWENTY-TWO STEEL RAILS BROKE UNDER MORE THAN 5 FEET OF FALL.

Feet of fall . .	9·5	17·5	23·5	24·5	24·5	26	37	44·5	44·5	44·5
Composition—										
Phosphorus . .	0·05	0·04	0·04	0·05	0·06	0·038	0·06	0·026	0·031	0·070
Carbon . . .	0·40	0·37	0·55	0·49	0·39	0·41	0·39	0·54	0·41	0·398
Sulphur . . .	0·10	0·10	0·04	0·04	0·06	0·12	0·12	0·05	0·06	0·075
Silicon . . .	0·08	0·08	0·19	0·15	0·48	0·066	0·08	0·102	0·153	0·041
Manganese . .	0·81	0·72	1·53	1·16	0·98	0·98	0·80	0·58	0·86	0·477
Totals . . .	1·44	1·31	2·35	1·89	1·97	1·614	1·45	1·298	1·514	1·061
Years in use . .	18·66	16·75	17	17	17	21·41	18·66	19·08	19	19·83
Loss per yard lbs.	11	10·75	2·75	3·25	2·63	3·13	8·25	10·63	8·30	7·63
Worn head. . .	up	up	up	down	down	down	up	down	down	down

NOTE.—The falling-weight tests referred to in these two

Sir Lowthian Bell.

AFTER REMOVAL FROM THE NORTH EASTERN RAILWAY SYSTEM WHICH
OF TUP, 2,240 LBS.; SUPPORTS, 3 FEET APART.

														Averages.
2·0	2·0	2·0	2·0	2·0	2·0	2·0	2·0	2·0	3·5	3·5	3·5	4·5	5·0	1·99
0·07	0·04	0·062	0·047	0·036	0·062	0·097	0·067	0·07	0·04	0·05	0·07	0·131	0·040	0·060
0·42	0·49	0·43	0·43	0·45	0·338	0·291	0·42	0·37	0·52	0·39	0·39	0·480	0·57	0·444
0·11	0·06	0·03	0·10	0·15	0·071	0·066	0·08	0·14	0·03	0·10	0·06	0·125	0·05	0·090
0·04	0·08	0·066	0·12	0·048	0·096	0·121	0·120	0·11	0·10	0·22	0·05	0·015	0·132	0·087
0·54	0·70	1·04	0·81	0·73	0·711	0·831	0·73	0·80	0·82	0·59	0·53	0·565	0·99	0·727
1·18	1·37	1·228	1·507	1·414	1·278	1·206	1·417	1·49	1·51	1·35	1·10	1·316	1·782	1·408
19	17	15	10	11·25	17·58	20·50	21·41	18·66	18	19	18	19	21·16	17·65
3·38	2·13	23·75	10	14·30	5·13	7·13	5·88	8·50	9	5·88	6·63	3·25	4·13	7·66
down	down	..	up	down	down	down	down	up	up	up	up	down	down	..

AFTER REMOVAL FROM THE NORTH EASTERN RAILWAY SYSTEM WHICH
WEIGHT OF TUP, 2,240 LBS.; SUPPORTS, 3 FEET APART.

												Averages.
48	58	63	65	76½	76·5	79·5	86·5	86·5	86·5	103·5	103·5	55·86
0·140	0·04	0·07	0·012	0·04	0·03	0·04	0·04	0·105	0·155	0·04	0·03	0·055
0·542	0·65	0·40	0·53	0·39	0·31	0·59	0·48	0·386	0·538	0·38	0·38	0·451
0·140	0·03	0·12	0·05	0·03	0·05	0·03	0·02	0·028	0·123	0·02	0·05	0·066
0·014	0·14	0·07	0·096	0·08	0·06	0·12	0·12	0·207	0·118	0·07	0·06	0·112
0·600	1·09	0·70	0·97	0·88	0·85	1·20	1·16	0·577	0·512	1·03	1·21	0·895
1·436	1·90	1·36	1·658	1·42	1·30	1·98	1·82	1·303	1·146	1·54	1·73	2·588
17	17	19	15·33	7·83	7·08	17	17	13·75	19	7·33	7·08	..
2·13	1·75	3·13	10	1·20	5·30	2	1	4·40	2·85	..	5·20	..
down	up	down	up	up	up	up	down	down	down	up	up	..

Tables were carried out in the manner indicated in the Paper.

Sir Lowthian Bell. any treatment capable of changing the objectionable variety into the other form?

NORTH EASTERN RAILWAY.

No.	Fall of Weight. — Feet.	Composition.						
		Phosphorus.	Carbon.	Sulphur.	Silicon.	Manganese.	Slag.	Total Foreign.
4	86½	0·155	0·538	0·123	0·018	0·512	0·064	1·410
5	86½	0·105	0·386	0·028	0·207	0·577	0·046	1·349
3	48	0·140	0·542	0·140	0·014	0·600	0·064	1·500
9	44½	0 070	0·398	0·075	0·041	0·477	0·066	1·127
2	4½	0·131	0·480	0·125	0·015	0·565	0·080	1·396
6	4½	0·078	0·454	0·062	0·041	0·614	0·072	1·321
7	2	0·062	0·338	0·071	0·096	0·711	0·078	1·356
8	2	0·097	0·291	0·066	0·121	0·631	0·088	1·294
Averages	34·81	0·105	0·428	0·086	0·069	0·586	0·069	1·344

EIGHT RAILS, LANCASHIRE AND YORKSHIRE RAILWAY.

No.	Fall of Weight. — Feet.	Composition.						
		Phosphorus.	Carbon.	Sulphur.	Silicon.	Manganese.	Slag.	Total Foreign.
11	26	0·098	0·335	0·070	0·075	0·838	0·082	1·498
12	26	0·066	0·374	0·091	0·054	0·796	0·070	1·451
15	26	0·079	0·415	0·044	0·092	1·144	0·086	1·860
13	17	0·058	0·371	0·091	0·063	0·804	0·064	1·451
16	17	0·066	0·371	0·054	0·055	1·089	0·066	1·621
14	10	0·072	0·412	0·069	0·094	0·910	0·058	1·615
15	2	0·061	0·329	0·080	0·055	0·693	0·078	1·296
17	2	0·070	0·348	0·094	0·050	1·061	0·098	1·721
Averages	16	0·071	0·369	0·074	0·067	0·917	0·075	1·564

In reply to a further question by Mr. Jordan, the sleepers used on the North Eastern line had a width of 10 inches, and the distance between two sleepers was 1 foot 11½ inches. This distance between the sleepers was maintained throughout, irrespective of differences in the traffic. An exception was observed at the junction of two rails, where the sleepers were only 1 foot 3½ inches apart. In the case of sharp curves the distance between each sleeper was reduced to 1 foot 8½ inches. The rails now in use on the North Eastern system had a length of 30 feet, and weighed 900 lbs. each., or 90 lbs. per yard. They were placed in chairs of cast iron, in which they were secured by wooden keys.

Mr. Andrews. Mr. T. ANDREWS, replying to the Correspondence, remarked, in reference to the question as to whether the separated sulphides had been responsible in any way for the wear of the rail,

that he had stated in the Paper that the wear of the rail had been due principally to the heavy amount of work put upon it; and after having carefully studied the structure of the rail, he considered further that the peculiar way in which the sulphides of iron and of manganese had micro-segregated in many places in this rail had undoubtedly intensified the effects of the heavy wear. The way in which these innumerable micro-segregations of the impurities had locally disturbed the normal micro-structure of the mass of the steel, and hence to that extent had affected the wearing qualities of the rail, was manifest on referring to the typical illustration given in Fig. 4, Plate 2. He observed Mr. Stead inferred that the sulphides in steel rails were isolated, and therefore mechanically harmless. This was often the case, but he had noticed in various other instances, both in fractured steel rails examined by him for various railway companies, and in fractured propeller-shafts and other forgings, that the sulphides, in a more or less attenuated condition, were not infrequently locally connected in various parts of the mass of the steel, and hence destroyed for appreciable distances that metallic contact between the ultimate crystals of the metal which was essential to ensure permanent strength. On the subject of the evil effects of sulphur in steel, he would direct attention to the series of articles he had recently published on "Microscopic Internal Flaws inducing Fracture in Steel,"[1] and on "Deterioration in Steel Rails."[2] It had been suggested that 0·10 per cent. of sulphur was not detrimental to steel rails. It should, however, be pointed out that such a high percentage would allow makers to use a commoner quality of pig-iron than was desirable for good rail-steel. He had found no difficulty in obtaining rails not containing more than 0·07 per cent. of sulphur. He had examined for railway companies rails with a comparatively high percentage of sulphur, some of which had worn down badly and had had comparatively short lives, whilst others from the same cause had actually fractured in service. He was sorry Mr. Stead attempted to minimize the evil effects of sulphur in steel rails, as it was evident that the less of such a "deadly enemy" (as Professor Arnold styled it) or impurity there was present in rails the greater their endurance would be, and advocacy of so high a percentage of sulphur as 0·10 in steel rails would appear to be detrimental to the interests of the public safety. Mr. Andrews.

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[1] *Engineering*, 10th, 17th and 24th July 1896.
[2] *Ibid*, 1897 and 1898.

ANNUAL GENERAL MEETING.

24 April, 1900.
Sir DOUGLAS FOX, President,
in the Chair.

The Notice convening the Meeting was taken as read, as well as the Minutes of the Annual General Meeting of the 25th April, 1899, which the President was authorized to sign.

The Report of the Council upon the Proceedings of the Institution during the Session 1899–1900 was read, the Statement of Accounts being taken as read.

After consideration, it was resolved,—That the Report of the Council be received and approved, and that it be printed in the Minutes of Proceedings.

The Scrutineers reported the election of the Council for 1900–1901 as follows:—[1]

President.

JAMES MANSERGH.

Vice-Presidents.

Sir William Henry White, K.C.B., D.Sc., LL.D., F.R.S.
Charles Hawksley.
John Clarke Hawkshaw, M.A.
Francis William Webb.

Other Members of Council.

James Barton, B.A.
Horace Bell.
Sir Alexander Richardson Binnie.
Benjamin Hall Blyth, M.A.
Henry Taylor Bovey, M.A., LL.D.
Cuthbert Arthur Brereton.
Thomas Forster Brown.
Robert Elliott Cooper.
George Frederick Deacon.
William Robert Galbraith.
George Henry Hill.
James Charles Inglis.
Alexander Izat, C.I.E.
Alexander Blackie William Kennedy, LL.D., F.R.S.
Sir James Kitson, Bart., M.P.
Anthony George Lyster.
John Allen McDonald.
Edward Pritchard Martin.
William Matthews.
Sir Guilford Lindsey Molesworth, K.C.I.E.
Alexander Siemens.
Thomas Stewart.
John Isaac Thornycroft, F.R.S.
William Thwaites, M.A.
William Cawthorne Unwin, B.Sc., F.R.S.
Sir Edward Leader Williams.

[1] The Council commence their year of office on the first Tuesday in November, 1900.

Resolved,—That the thanks of the Meeting be given to the Scrutineers, and that the Ballot-Papers be destroyed.

Mr. John J. Webster responded on behalf of the Scrutineers.

Resolved,—That the thanks of the Institution be tendered to Messrs. John George Griffiths and Cuthbert Arthur Brereton, for the time and trouble bestowed by them in auditing the Accounts for the past financial year; and that Messrs. John George Griffiths and Alexander Ross be appointed Auditors for the ensuing year.

Messrs. Griffiths and Brereton acknowledged the Resolution.

Resolved,—That the thanks of this Meeting be accorded to Sir Douglas Fox, President, for his conduct of the business as Chairman of the Meeting.

The President acknowledged the Resolution.

The proceedings then ended.

REPORT OF THE COUNCIL, 1899-1900.

THE Council present the following Report on the state of the Institution, dealing with the ordinary proceedings of the past 12 months, and with the register and the accounts for the financial year ended on the 31st March.

It will be seen that the corporate membership has increased in both classes, although in a less marked degree than when the conditions of entrance were less exacting. The numbers attending the examinations show considerable increase—a total of 238 Candidates having been examined during the year, as compared with 182 in the previous year. This department of the Institution work exhibits corresponding activity, 42 separate papers having been set by the Examiners, with the concomitant marking and registration of the results contained in some 1,200 books of answers. In addition 46 theses have been received and examined by the Council. Generally, the performances of the Candidates have been satisfactory and encouraging.

Reference was made in the Report of the last Council to the condition that admittance to the Institution involved that the applicant should be "regularly educated as a Civil Engineer" in some branch of the profession. It has seemed to their successors desirable that the *regular education* contemplated by the By-laws should be indicated more definitely for the information of intending Candidates for election, as well as for the guidance of engineering students.

Consequently the Council, after very careful consideration, framed the following regulations dealing with this matter of training, apart from the examination or other tests in force, which have been lately communicated to the members:—

(*a*) ADMISSION OF STUDENTS.

(1) In cases where the usual routine of pupilage is being, or has been, served under a Corporate Member, the pupil may be proposed as a Student at any time after the commencement of such pupilage.

(2) In cases where a course of training at any public institution approved by the Council is being, or has been, pursued under a teacher who is a Corporate Member, the latter may propose a pupil for admission as a Student after he has commenced a second year of training at such institution.

(3) A Corporate Member may propose for Studentship an Assistant who has been in his office or works for a period of not less than 3 years.

(*b*) Election.

(1) In the case of a Candidate who has only received the general education required for Studentship of the Institution, a pupilage or a training as an Assistant of not less than 3 years' duration is required, and during this time the Candidate shall have given his attention to various branches of work, partly in an Engineer's office and partly in or upon Engineering works.

(2) In the case of a Candidate whose education has included a college course in scientific subjects, a pupilage or a training as an Assistant of not less than 2 years' duration is required, and during this time the Candidate shall have given his attention to various branches of work, partly in an Engineer's office and partly in or upon Engineering works.

At the same time the Council deemed it expedient to make certain additions to the Forms for Election, Admission and Transfer, which they hope will be of assistance both to Candidates and to their supporters, in presenting the required statements of qualification.

The examination of these statements, it may be observed, constitutes one of the most important duties of the Council. Seven hundred and eighty-six Forms have passed under their scrutiny during this Session; and they have to acknowledge the ready aid given by many members of the Institution who have assisted with information when called upon to do so.

The Roll.

The changes which have taken place in the Roll during the year ending the 31st March, 1900, are shown in the accompanying Table. The elections comprised 26 Members, 192 Associate

—	April 1, 1898, to March 31, 1899.						April 1, 1899, to March 31, 1900.					
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.		Honorary Members.	Members.	Associate Members.	Associates.	Totals.	
Numbers at commencement	20	1,964	3,924	321		6,229	20	2,004	3,953	326		6,303
Transferred to Members	..	65	65	..			..	79	79	..		
Elections	2	28	159	14	214		..	26	192	5	232	
Restored to Register	..	2	9	..			..	2	6	1		
Deaths	2	47	26	6	140		1	55	33	14	183	
Resignations	..	5	22	2			..	14	20	2		
Erased	..	3	26	1	—	74	..	9	30	5	—	49
Numbers at termination	20	2,004	3,953	326		6,303	19	2,033	3,989	311		6,352

Members and 5 Associates; and there were restored to the register the names of 2 Members, 6 Associate Members, and 1 Associate—representing a total addition of 232. From this must be deducted 183 names which, owing to death, resignation and erasure, were removed from the list, leaving a net increase of 49. The number of elections to the Associate Member class exceeded those of the two preceding Sessions by 33 and 53 respectively, when the check due to the examinations introduced in 1897 was more distinctly felt. On the other hand, the losses during the term under review have been unusually heavy, exceeding those of the previous year by 43. The number on the Roll, exclusive of Students, on the 31st March, was 6,352, as against 6,303 on the corresponding date of last year; the total number being 7,359.

Among the deceases recorded are those of Sir Edward Frankland, the distinguished Chemist and Honorary Member; George Graham, Member of Council; George Fosbery Lyster, formerly a Member of Council; and Colonel Sir John Graham McKerlie, for nearly 49 years an Associate of the Institution.

The full list of deceases is as follows:—

Honorary Member.—Sir Edward Frankland, K.C.B., M.D., D.C.L. (*Oxon.*), LL.D. (*Edin.*), F.R.S.

Members.—John Orme Andrews; James Arthur Anderson; George Augustus d'Auvergne Anley; James Danford Baldry; Henry Wollaston Blake, M.A. (*Cantab.*), F.R.S.; Horatio Brothers; Peter Schuyler Bruff; John Brunton; William Butterton; Edward Cousins; Frederick Bernard Doering; Thomas Weatherburn Dodds; John Donaldson; Paul Bedford Elwell; Joseph Fogerty; Rogers Field, B.A. (*Lond.*); William Foggin; Joseph Garland; Edward Garlick; William Gilchrist Gilchrist; Robert Gillham; George Graham, *Member of Council;* George Gregory; Alfred Ephraim Hunt; James Bernard Hunter; Hortensius Huxham; Warwick Huson Johnson; John Hawthorn Kitson; John Lanyon; Frank Livesey; George Fosbery Lyster, *formerly Member of Council*; Alexander Kendall Mackinnon; Alexander Hill Macnair; Henry Maudslay; Benjamin Theophilus Moore, M.A. (*Cantab.*); William Morton; John Napier; Matthew James Joseph Patrick Norman; Lindley William Paynter; John Baldry Redman; Robert Reynolds: Francis Rinecker; Samuel Ussher Roberts, C.B.; Murrell Robinson Robinson; Richard Reynolds Rowe; Macnamara Russell; James Corry Sherrard; Henry Simon; George Ernest Stevenson; Samuel Utley; Henry Vignoles; Henry Wakefield: William Wilkinson Wardell; Frederick Charles Webb; and Thomas Haines Wickes.

Associate Members.—William Richard Acton; William Phillipson Anningson; John Anstie, B.A. (*Lond.*); Thomas Gibson Barlow-Massicks; George Barclay Bruce; Professor William Kinninmond Burton; Edward Case: Thomas Stanley Cleminshaw; William Cross; Thomas Gibson; Charles Edward Goodfellow; Henry Sebastian Hart; Edward Charles Hodge; Charles Morris Jenkins; John Knight; Thomas Elcoat Laing; Alfred Davis Lewis; Thomas Lawrence Lewis; Percy William Mavor; James Morgan; M. Labeeb Mossallem; Henry Arthur Casperez Müller; Joseph Newton; William Barron Norton; William Penman; Joseph Potts; Edward John Prew; Griffith Roberts; Thomas Roberts;

Frederick William Slaughter; Josias Edward de Villiers; Nowrosjee Nesserwanjee Wadia, C.I.E.; and James Douglas Wallace.

Associates.—Robert Capper; Edward Corry; Edward Crofton, M.A. (*Oxon.*); George Furness; Francis Henry Izard; John Henry Johnson; Sir John Graham McKerlie, *Colonel* R.E. *retired*, K.C.B.; William Ellis Metford; George Henry Ogston; John Henry Pepper; Daniel Pidgeon; William Piper; Alexander de Courcy Scott, *Major-General* R.E. *retired*; and George Woolcott.

The following resignations have been accepted:—

Members.—Emerson Bainbridge, M.P.; George Berkley; Roscoe Bocquet, C.I.E.; Marcelin John Chabrel, B.E. (*Queen's*); William Palliser Costobadie; Henry Arthur Dibbin; Arthur Staples Gerrard; Charles Booth Jones, B.A. (*Dubl.*); John Gale Jopp; Horace Chaloner Knox; Thomas Ross Salmond; Henry Mungo Thompson, B.A. (*Dubl.*); Claude Vincent; and Frederick Wells.

Associate Members.—Harry Anstey; Herbert Richard Francis Ash; John Banks; George Vaughan Brown; John Thomas Brown; Evaristo de Chirico; Arthur Cecil Crampton; Walter Augustus Ducat; David John Russell Duncan; Sir Malcolm Fraser, K.C.M.G.; Frank Harris, B.A. (*Oxon.*); Herbert Spong Hawkins; William James Hodgson; James Jones; George McLellan; Henry Reilly; James Thomas Sheldrick; Isaac Shone; Edward Venning; and Herman George Wilson.

Associates.—Hugh Henry Swan; and James Williams.

Admission of Students.

The Table appended shows the changes which have taken place in the Student class during the twelve months ending the 31st March. The admissions, amounting to 263, exceeded those of the previous year by 43. The deductions from the list reached the large total of 220, of whom as many as 158 were removed on attaining the age-limit. Judging from the experience of past years a large number of these will apply for election

Students.

1898–99.

April 1, 1898 . . .			947
Admitted during the year	220		
Restored to List . .	1		
	—	221	
Elected Associate Members	31		
Elected Associate . .	1		
Resigned	17		
Deceased	1		
Erased	1		
Removed—over age .	153		
	—	204	
		—	17
			—
March 31, 1899 . .			964

1899–1900.

April 1, 1899 . . .			964
Admitted during the year	..	263	
Elected Associate Members	36		
Resigned	18		
Erased	8		
Removed—over age .	158		
	—	220	
		—	43
			—
March 31, 1900 . .			1,007

to the Associate Member class; of the 192 candidates elected to that class during the year under review, 89 were, or had been formerly, students. The total number of Students on the 31st March amounted to 1,007, as against 964 on the corresponding date of last year.

FINANCE.

The Statement of Accounts, verified by the Auditors, is given at p. 190.

The receipts during the year were as follows: On Income account £22,735 1*s.* 8*d.*, consisting of subscriptions £18,955 8*s.*, dividends £1,667 10*s.*, rents £980 4*s.*, examination fees £387 9*s.*, and miscellaneous items £744 10*s.* 8*d.*; on Capital account £2,470 13*s.*, being admission fees and life compositions; and from Trust Funds £470 8*s.* 11*d.*: the total being £25,676 3*s.* 7*d.* The expenditure was: amount chargeable to Income £21,465 17*s.* 2*d.*, of which rates and taxes absorbed £1,154 17*s.* 1*d.*, and publications £8,177 4*s.* 9*d.*; and to Trust Funds £517 5*s.* 7*d.*

The investments on Institution account amount to £53,600 (nominal value), purchased for £54,884 5*s.* 8*d.*, and the Funds held in Trust to £17,144 0*s.* 9*d.* (cost price).

SESSIONS AND MEETINGS.

Twenty-one ordinary meetings were held during the Session, at which seventeen Papers were read and discussed. The titles of these memoirs suggest that Engineering is still pre-eminently concerned with the improvement of means of communication—to which subject the President's inaugural Address was principally devoted. It has been remarked in previous Reports that no attempt is made by the Council to guide the work of the Session into one particular channel, yet it happens for the most part that subjects chosen for discussion at the meetings indicate more or less closely the main objects of engineering interest at the time. Of the Papers read during the session one-half relate directly to railways, while several others refer directly or indirectly to communication by water.

Taking the Papers *seriatim*, the descriptions, by Messrs. Dalrymple-Hay and Jenkin, respectively of the "Waterloo and City Railway" and the "Electrical Equipment of the Waterloo and City Railway" elicited a most interesting and valuable discussion extending over portions of four evenings. A Paper on "Swing-

Bridges on the River Weaver at Northwich," by Mr. J. A. Saner, described a novel and ingenious mode of applying the principle of flotation to turning-bridges, whereby some of the objections to this class of structure are met in an efficient and economical manner. "Steamers for Winter Navigation and Ice-Breaking," by Mr. Robert Runeberg, whilst largely referring to questions of naval architecture, marked the successful efforts which have been made of late years to deal with the problem of continuously carrying on traffic to and from ice-bound harbours which were formerly inaccessible for a part of the year. "Moving-Loads on Railway Underbridges" and a "Note on the Floor System of Girder Bridges," by Messrs. W. B. Farr and C. F. Findlay, respectively, discussed the means to be adopted for coping with the greatly increased load to which railway bridges have of late years been subjected, owing to the employment of heavier rolling-stock. Sir Charles Hartley's "Short History of the Engineering Works of the Suez Canal" affords a valuable account of the initiation and of the development of that undertaking to meet the growing needs of international communication. The present practice in construction of a main line of railway is shown in two memoirs on the "Great Central Railway Extension: Northern Division," by Mr. F. W. Bidder, and "Southern Division," by Mr. F. Douglas Fox, and the discussion thereby elicited bore upon the measures now demanded to meet the more rapid construction of railways and the higher speeds employed on them. The Papers on "Economical Railway Construction in New South Wales," by Mr. Henry Deane, and "The Tocopilla Railway," by Mr. Robert Stirling, touched some questions of construction and of rolling-stock in relation to light railways. The account given by Sir Lowthian Bell of "The Development of the Manufacture and Use of Rails in Great Britain" traced the part played by the advances in rail-manufacture in the improvement of railway communication; and Mr. Thomas Andrews' Paper on "The Wear of Steel Rails in Tunnels" had also an important bearing on the subject of their manufacture.

Under this predominant subject of "Communications" the other matters considered during the Session may seem to be overshadowed, but they were nevertheless of considerable importance. Mr. C. N. Russell's Paper on "Combined Refuse-Destructors and Power Plants" induced a very useful discussion on one of the later developments of municipal engineering, while Messrs. R. A. Tatton and W. O. E. Meade-King, in their Papers entitled "The Purification of Water after its Use in Factories," and "Experi-

ments on the Purification of Waste-Water from Factories," referred to the serious efforts which are now being made in some districts to cope with the pollution of watercourses. Finally, Mr. John Dewrance in "The Corrosion of Marine Boilers," discussed the various theories advanced to account for the erratic phenomena of the "pitting" of boiler-plates—a subject of deep concern to both the commercial marine and of the navy.

Awards in respect to the foregoing have been made to Sir Lowthian Bell, Bart., Messrs. H. H. Dalrymple-Hay, B. M. Jenkin, F. W. Bidder, F. Douglas Fox, J. Dewrance, Sir Charles Hartley, and Messrs. C. N. Russell, and R. A. Tatton.

The Papers selected for publication in Section II of the Proceedings call for no special comment, unless it be that many of them involve a considerable knowledge of scientific literature and no little mathematical skill on the part of a careful student of the subjects. The awards made in this Section will as usual be announced in the Autumn.

The "James Forrest" Lecture.

The eighth "James Forrest" lecture dealing with "The Relation between Electricity and Engineering," was delivered by Sir William Preece, K.C.B., F.R.S., Past-President, at a well-attended special meeting on the 23rd April; and the Institution is under a further obligation to the lecturer for his kind repetition of the Address on the following afternoon.

Students' Meetings.

Nine Students' meetings have been held in London during the Session, at eight of which Papers were read and discussed, whilst at that held on the 12th January, Prof. T. Claxton Fidler, M. Inst. C.E., very kindly delivered a valuable lecture on the "Theory of Construction," a copy of which has been supplied to every Student. The usual visits to engineering works have been made fortnightly during the Session, and have been fairly well attended. In addition, thirteen Papers have been read by Students before meetings of the various local Associations, which all give evidence of continued prosperity. A special series of Students' visits in London has been arranged for the 26th and 27th April, on the latter of which days the Students' Twenty-fifth Annual Dinner is to be held.

General Business.

The Institution has, since the last annual meeting, received the portrait of Sir William Preece, K.C.B., Past-President, and six more busts of prominent engineers have been reproduced in marble from the plaster originals which formerly stood in the theatre.

The second Engineering Conference was held on the 7th, 8th, and 9th June, under somewhat more favourable conditions than the previous one, as regards accommodation—thanks to the courtesy of the Councils of the Institution of Mechanical Engineers and the Surveyors' Institution, and of the Middlesex County Council in placing rooms at the disposal of the Sections and Officers. The aggregate attendance at the meetings is not known, but must have been considerable, judging from the fact that 307 speakers are recorded as having taken part in the various debates, a complete report of which is filed in the library.

The Conference doubtless had some influence upon the attendance at the Conversazione, which was held at the Institution on the 8th and 9th June, when the President received 3,300 of the members and their friends.

In the present year it is intended that the annual Conversazione shall take place in the City Guildhall, which has most kindly been placed at disposal for this purpose by the Corporation. The President and Council hope to meet the members of the Institution there on the 5th July, and at the same time to extend a cordial welcome to the American engineers who are to be then in London.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	s.	d.	£.	s.	d.
To Balance, 1 April, 1899, viz.:—						
On Deposit	5,000	0	0			
Cash in the hands of the Treasurer	2,016	2	11			
" " " Secretary	11	19	8			
				7,028	2	7

INCOME.

	£.	s.	d.	£.	s.	d.	£.	s.	d.
— Subscriptions received:—									
Arrears, prior to 1 January, 1899	410	11	0						
For the year 1899	4,562	17	6						
For the year 1900	13,971	9	6						
Advance	10	10	0						
				18,955	8	0			
— Minutes of Proceedings:—Repayment for Binding, &c.				552	14	8			
— Library Fund				131	1	0			
— Dividends: 1 year on									

Institution Dividends.

£		£.	s.	d.	£.	s.	d.
2,000	$2\frac{3}{4}$% Consols	53	8	4			
6,000	Metropolitan $3\frac{1}{2}$% Stock	203	0	0			
6,000	Great Eastern Railway 4% Debenture Stock	232	0	0			
8,000	Great Northern Ry. 3% Debenture Stock	232	0	0			
8,000	Great Western Ry. 4% Debenture Stock	309	6	8			
8,000	Lancs. & Yorks. Ry. 3% Debenture Stock	232	0	0			
6,000	London & N.W. Ry. 3% Debenture Stock	174	0	0			
9,600	Midland Ry. $2\frac{1}{2}$% Debenture Stock	232	0	0			
£53,600	Nominal or par value.				1,667	10	0

	£.	s.	d.	£.	s.	d.	£.	s.	d.
— Rents—No. 27 Great George St.:—									
One year	955	4	0						
Advance	25	0	0						
				980	4	0			
— Examination Fees				387	9	0			
— Interest on Deposit				60	15	0			
							22,735	1	8
Carried forward							£29,763	4	3

from the 1st APRIL, 1899, *to the* 31st MARCH, 1900.

EXPENDITURE.

Cr. General Expenditure.

By House and Establishment Charges:—	£.	s.	d.	£.	s.	d.	£.	s.	d.
Repairs:— General	108	17	4						
No. 27 Gt. George St.	2	0	6						
				110	17	10			
Rent of No. 27 Great George Street				600	0	0			
Rates and Taxes:—The Institution	974	11	8						
No. 27 Gt. George St.	180	5	5	1,154	17	1			
Insurance:—The Institution	84	12	6						
No. 27 Gt. George St.	3	0	0						
				87	12	6			
Fixtures and Furniture, Marble Busts, etc.				545	9	4			
Lighting, Warming and Ventilating:—									
The Institution	298	3	7						
No. 27 Gt. George St.	9	6	8						
				307	10	3			
Charges for Water (including lifts), Rent of Telephone, &c.	102	15	0						
Charges for Water, No. 27 Gt. George St.	18	6	0	121	1	0			
Refreshments at Meetings				89	15	8			
Assistance at Meetings				22	17	0			
Students' Meetings (including refreshments), Donation to Annual Dinner, and Visits				234	5	8			
Household Expenses				411	17	7	3,686	3	11
— Postages, Telegrams, and Parcels				330	12	2			
— Stationery and Printing				779	10	0			
— Watt Medals				4	15	0			
— Stephenson Medals				4	15	0			
— Diplomas				7	1	2			
— Annual Dinner (balance of 1899 and part 1900)				297	8	3			
— Conversazione				1,327	3	0			
— Conference				543	6	9	3,294	11	4
— Salaries				2,337	10	0			
— Clerks, Messengers, and Housekeeper				1,484	12	4			
— Retiring Allowances and Donations				1,276	11	8	5,098	14	0
— Library:—Books and Periodicals				276	16	8			
Binding				291	7	7	568	4	3
— Publications:—									
"Minutes of Proceedings," Vols. cxxxvi., cxxxvii., cxxxviii. and cxxxix.				8,005	9	7			
Charters, By-Laws, and Lists of Members				171	15	2	8,177	4	9
Carried forward							£20,824	18	3

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.

	£.	s.	d.
Brought forward	29,763	4	3

CAPITAL.

	£.	s.	d.	£.	s.	d.
To Admission-Fees	2,281	13	0			
— Life-Compositions	189	0	0			
				2,470	13	0

Carried forward . .	£32,233	17	3

from the 1ST APRIL, 1899, *to the* 31ST MARCH, 1900.

EXPENDITURE—*continued.*

Cr.		£. s. d.
Brought forward		20,824 18 3
— Professional Auditor's Fee	105 0 0	
— Examinations (including printing, stationery, etc.)	523 8 11	
— Donation to Westminster Hospital	10 10 0	
Paris Exhibition—Congress Subscriptions . . .	2 0 0	
		640 18 11
		21,465 17 2

Carried forward . . £21,465 17 2

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.		£. s. d.	£. s. d.	£. s. d.
	Brought forward			32,233 17 3
	TRUST FUNDS.			
	Telford Fund.			
To Dividends:—1 year on				
£. s. d.				
5,439 11 0	2¾% Consols	144 12 4		
3,299 2 0	Ditto (Unexpended Dividends) . . .	87 14 0		
£8,738 13 0			232 6 4	
	Manby Donation.			
£250 0 0	Great Eastern Ry. 4% Irredeemable Guaranteed Stock	. . . .	9 13 4	
	Miller Fund.			
3,125 0 0	2¾% Consols. . . .	83 1 4		
2,004 17 5	Ditto (Unexpended Dividends). . . .	53 6 0		
£5,129 17 5			136 7 4	
	Howard Bequest.			
£551 14 6	2¾ % Consols		14 13 4	
	Trevithick Memorial.			
£103 0 0	2¾ % Consols		2 14 8	
	Crampton Bequest.			
£512 15 11	2¾% Consols.		13 12 8	
	James Forrest Lecture and Medal Fund.			
372 0 0	South-Eastern Ry. 5% Debenture Stock . . .		17 19 7	
	Palmer Scholarship.			
1,381 1 6	Metropolitan 3% Stock .	40 1 0		
104 18 5	Ditto (Unexpended Dividends) . . .	3 0 8		
£1,485 19 11			43 1 8	
				470 8 11
				£32,704 6 2

from the 1st APRIL, 1899, *to the* 31st MARCH, 1900.

EXPENDITURE—*continued.*

Cr.

	£. s. d.	£. s. d.	£. s. d.
Brought forward			21,465 17 2
Trust Funds.			
By Telford Premiums	289 3 3		
— Telford Medals	9 0 0		
		298 3 3	
— Manby Premium		16 0 0	
— Miller Prizes		114 15 0	
— Crampton Prizes		27 15 0	
— "James Forrest" Lecture (seventh)	14 0 0		
James Forrest Medal	2 15 0		
		16 15 0	
— Palmer Scholarship—			
1 year's dividend to Scholar	43 1 8		
Balance due from previous year to Scholar	0 15 8		
		43 17 4	
			517 5 7
			21,983 2 9
— Balance, 31 March, 1900, viz.:—			
On Deposit		6,000 0 0	
Cash in the hands of the Treasurer		4,718 7 10	
„ „ Secretary		2 15 7	
			10,721 3 5
			£32,704 6 2

J. H. T. Tudsbery, *Secretary*.
10 *April*, 1900.

Examined with the Books and Securities and found correct.

(Signed) John G. Griffiths, F.C.A. / Cuthbert A. Brereton. } *Auditors.*

STATEMENT OF INVESTMENTS HELD 31 MARCH, 1900.

Institution Investments.

£			£.	s.	d.	£.	s.	d.
2,000	2¾% Consols	Cost	1,967	19	1			
6,000	Metropolitan 3½% Stock	„	6,517	15	0			
6,000	Great Eastern Railway 4% Debenture Stock	„	7,749	18	3			
8,000	Great Northern Railway 3% Debenture Stock	„	7,642	16	4			
8,000	Great Western Railway 4% Debenture Stock	„	10,547	5	0			
8,000	Lancashire and Yorkshire Railway 3% Debenture Stock	„	7,452	14	8			
6,000	London and North Western Railway 3% Debenture Stock	„	5,544	18	5			
9,600	Midland Railway 2½% Debenture Stock	„	7,460	18	11			
53,600						54,884	5	8

	£.	s.	d.
Freehold of Institution Premises and New Building:— Cost, including buildings now removed	124,379	10	0

Note.—No value has been attached, for the purpose of this statement, to the Books, Furniture, Fittings, Pictures, &c., in the Institution Building nor to the lease of No. 27 Great George Street.

Trust Funds Investments.

Telford Fund.

£.	s.	d.			£.	s.	d.
1,945	19	0	2¾% Consols	Acquired with a bequest of	2,000	0	0
3,479	12	9	do.	Converted from Government Stocks bequeathed	Bequest.		
13	19	3	do.	Purchased with bonus on conversion cost	13	11	3
5,439	11	0					
3,299	2	0	do.	Purchased with unexpended dividends	3,034	18	1
8,738	13	0					

Manby Donation.

£.	s.	d.		
250	0	0	Great Eastern Railway 4% Irredeemable Guaranteed Stock	Donation.

Miller Fund.

£.	s.	d.			£.	s.	d.
3,125	0	0	2¾% Consols	Acquired with a bequest of	3,000	0	0
2,004	17	5	do.	Purchased with unexpended dividends	1,850	2	4
5,129	17	5					

TRUST FUNDS INVESTMENTS—*continued.*

£.	s.	d.		£.	s.	d.
			Howard Bequest.			
551	14	6	2¾% Consols—Acquired with a bequest of . .	500	0	0
			Trevithick Memorial.			
103	0	0	2¾% Consols—Acquired with a presentation of .	100	0	9
			Crampton Bequest.			
512	15	11	2¾% Consols—Acquired with a bequest of . .	500	0	0
			James Forrest Lecture and Medal Fund.			
320	0	0	South Eastern Railway 5% Debenture Stock acquired with a subscription of.	510	0	0
52	0	0	Ditto acquired with a subscription of £93 14*s.* 8*d.* and 19*s.* 4*d.* cash	94	14	0
372	0	0				
			Palmer Scholarship.			
1,381	1	6	Metropolitan 3% Stock bequeathed	Bequest.		
104	18	5	Ditto purchased with unexpended dividends. .	122	6	3
1,485	19	11				

MEDALS AND PREMIUMS AWARDED FOR THE SESSION 1898–99, PRESENTED ON THE 7TH NOVEMBER, 1899.

FOR PAPERS READ AND DISCUSSED AT THE ORDINARY MEETINGS.

1. A George Stephenson Medal and a Telford Premium to Robert Abbott Hadfield,[1] M. Inst. C.E., for his Paper on "Alloys of Iron and Nickel."
2. A Telford Medal and a Telford Premium to James Tayler Milton, for his Paper on "Water-Tube Boilers for Marine Engines."
3. Watt Medals and Telford Premiums to Sir Albert John Durston,[2] K.C.B., R.N., M. Inst. C.E., and to Henry John Oram, R.N., M. Inst. C.E., for their Paper "Recent Trials of the Machinery of War-Ships."
4. A Crampton Prize to Francis Fox,[3] M. Inst. C.E., for his Paper on "The Ventilation of Tunnels and Buildings."
5. The Manby Premium to Sir William Chandler Roberts-Austen,[4] K.C.B., F.R.S., Assoc. Inst. C.E., for his Paper on the "Extraction of Nickel by the Mond Process."
6. A Telford Premium to James Murray Dobson, M. Inst. C.E., for his account of the "Buenos Ayres Harbour Works."
7. A Telford Premium to William George Kirkaldy, Assoc. M. Inst. C.E., for his Paper on the "Effects of Wear upon Steel Rails."
8. A Telford Premium to Jeremiah Head,[5] M. Inst. C.E., and Archibald Potter Head, Assoc. M. Inst. C.E., for their Paper descriptive of the "Lake Superior Iron-Ore Mines."

FOR PAPERS PRINTED IN SECTION II OF THE PROCEEDINGS FOR THE SESSION 1898–99.

1. Telford Medals and Telford Premiums to Ludwig Franzius and George Henry de Thierry for their Paper, "River Regulation Works and Harbour and Canal Construction in Germany."

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[1] Has previously received a Telford Medal and Premium.

[2] Has previously received a George Stephenson Medal and a Telford Premium.

[3] Has previously received Telford and George Stephenson Medals, a Crampton Prize and Telford Premiums.

[4] Has previously received a Telford Premium.

[5] Has previously received a Watt Medal and a Telford Premium.

2. A George Stephenson Medal and a Telford Premium to George Watson, Assoc. M. Inst. C.E., for his Paper on "Refuse Furnaces."
3. A Telford Premium to Leveson Francis Vernon-Harcourt,[1] M.A., M. Inst. C.E., for his Paper on "The Brussels International Congress on Navigation of 1898; the Bruges Ship-Canal; and New Works at Ostend and Antwerp."
4. A Telford Premium to Floris Osmond, for his Paper on "Experiments on Alloys of Iron and Nickel."
5. A Telford Premium to Max am Ende,[2] M. Inst. C.E., for his Paper, "Suspension Bridges with Stiffening Girders."
6. A Telford Premium to Thomas Ernest Stanton, D.Sc., Assoc. M. Inst. C.E., for his Paper on "The Efficiency and Design of Surface-Condensers."
7. A Telford Premium to William George Hibbins, for his Paper, "Experiments upon the Action of Engine-Governors."
8. A Telford Premium to James Strachan,[3] C.I.E., M. Inst. C.E., for his description of the "Karachi Sewerage Works."
9. A Telford Premium to Thornycroft Donaldson, M.A., Assoc. M. Inst. C.E., for his Paper, "Stresses in Pipes bent at Right Angles caused by Heating to the Temperature of Steam at various Pressures."
10. A Telford Premium to Thomas Walter Barber, M. Inst. C.E., for his Paper on "The Victoria Bridge over the Dee at Queensferry."

For Papers Read before Meetings of Students at the Institution.

1. The "James Forrest" Medal and a Miller Prize to Herbert Lapworth, Stud. Inst. C.E., for his Paper on "The Construction of the Elan Aqueduct, Rhayader to Dolau."
2. A Miller Prize to Frank Corbett Grimley, Stud. Inst. C.E., for his description of the "King's Lynn Water Supply."
3. A Miller Prize to William Middleton, Stud. Inst. C.E., for his Paper on "The Electrical Driving of Engineering Workshops."

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[1] Has previously received a Telford Medal and Telford and Manby Premiums.
[2] Has previously received a Telford Medal and Premium.
[3] Has previously received a Telford Premium.

For Papers Read before Local Associations of Students.

4. A Miller Prize to Frank Thomas Wolseley-Lewis, Stud. Inst. C.E. (Manchester), for his Paper on "Marine Engines."
5. A Miller Prize to Arthur Henry Tyack, Stud. Inst. C.E. (Manchester), for his Paper on "Turbines."
6. A Miller Prize to Robert Alan Erskine Murray, Stud. Inst. C.E. (Glasgow), for his description of the "Invergarry and Fort Augustus Railway."
7. A Miller Prize to Charles Rogers Rutherglen, Stud. Inst. C.E. (Glasgow), for his description of the "Duntocher and Dalmuir Waterworks."
8. A Miller Prize to William David Seton Brown, Stud. Inst. C.E. (Newcastle-upon-Tyne), for his Paper on "The Propelling Machinery of a Torpedo-Boat Destroyer."

SUBJECTS FOR PAPERS, PREMIUMS, AND INSTRUCTIONS FOR PREPARING ORIGINAL COMMUNICATIONS.

SESSION 1900–1901.

THE COUNCIL of The Institution of Civil Engineers invite Original Communications on the Subjects included in the following List, as well as on other questions of professional interest. This list is to be taken merely as suggestive, and not in any sense as exhaustive. For approved Papers the Council have the power to award Premiums, arising out of Funds bequeathed for the purpose, the particulars of which are annexed.

LIST OF SUBJECTS.

RAILWAYS.

1. The Efficiency of Railways as affected by gauge, with reference to (*a*) the character of the traffic and climatic conditions; (*b*) utility for Military purposes.
2. The effects of Break of Gauge on the working expenses of a Railway, with reference to the cost of transfer, the liability to loss and breakage, and the necessity for increased rolling stock and separate repairing-shops.
3. The relative advantages of exceptionally Steep, but short, Gradients, compared with longer, but less steep, gradients for ascending mountain passes.
4. The increase of Speed in express Travelling.
5. The use of Cast-Iron, Steel, and Wooden Sleepers; their suitability for various kinds of ballast, and the effects of salts contained in ballast, and of the sea air, upon them.
6. Rail-Depôts and Appliances for handling and stocking permanent-way materials.
7. The application of machinery in large Railway Goods-Yards and Sheds.
8. The handling of Luggage by machinery in large Passenger Stations.
9. Automatic Couplings and appliances for the Prevention of Accidents in Shunting.
10. The Erection of Girders, with or without scaffolding.

11. The design and construction of Railway Carriages, having reference to (*a*) lavatory accommodation; (*b*) provision for refreshments; (*c*) sleeping accommodation.
12. Standard and Metre-gauge rolling-stock on Indian railways, having reference to their relative capacity for (*a*) ordinary traffic; (*b*) Military transport and the carriage of heavy guns.
13. Street Railways, having reference to different systems of traction, viz., (*a*) steam; (*b*) cable conduit; (*c*) electric trolley; (*d*) electric rail contact; (*e*) electric conduit; (*f*) electric storage battery.

Waterways and Maritime Works.

14. The most economical Methods of Handling large masses of Excavation, as exemplified in modern canal construction.
15. The Measures necessary for the improvement of Canal Navigations.
16. The Dredging of Bars and Channels.
17. The Methods adopted in carrying out large Dock and Harbour Works, with descriptions of the Plant employed.
18. The Appliances for Dredging and for Removing Rock in deep water, with details of the time occupied in the various operations.

Machinery.

19. The Design and Construction of large Turbines.
20. The Forms of Turbine most suitable for Small Falls.
21. The most suitable Steam-power Equipments, and the size of units, for Electric-light stations.
22. The utilization of Wind-power.
23. The utilization of Wave- and Tide-power.
24. Modern Methods of Pumping compared with regard to cost and efficiency.
25. The Application of Compressed Air, Steam and Hydraulic power to Rock-drills and to other tools.
26. The Application of Steam-, Compressed-Air, Oil- and Gas-Engines to tractive purposes on common roads and on tramways.
27. The Theory and Development of the Compound Steam-Turbine.
28. The Strength of Steel Shafts, Tubes and Cylinders.
29. The most suitable Alloys for the Working Parts of Pumps for lifting Corrosive Liquids from mines, etc.

30. The Methods of Preventing or Arresting the Corrosion of Hydraulic Rams of large diameter.
31. The Methods of Testing the Lubricating Values of Oils, Greases, etc.
32. The Use of the Die-press in workshop operations.
33. The Appliances used in the Manufacture of Smokeless Powder.
34. The Utilization of Heat (*a*) generated in the compression of air and other gases; (*b*) carried away by steam-engine condenser-water; and (*c*) contained in boiler-furnace flue-gases.
35. The Methods of Condensing Steam by the use of moderate quantities of water.
36. The Methods of removing Moisture from Steam, and of reducing losses by radiation from steam-pipes.
37. The different systems of Refrigeration, and of appliances for the storage and Preservation of Food.
38. The Construction and Use of Water-Tube Boilers.

Mining and Metallurgy.

39. The Sinking of Shafts through Various kinds of Strata, including Sand, and the methods of dealing with large inrushes of water.
40. Boring-Machinery suitable for different kinds of Rock, having regard to rapidity of progress and reliability in the various strata traversed.
41. Mining-Machinery, inclusive of Compound Engines for Winding purposes.
42. Mechanical Appliances for Coal-getting.
43. The use of Explosives Underground in different kinds of strata, as well as under water and in connection with dusty and fiery Mines.
44. The Mining of Thick and of Thin Seams of Coal, under different conditions of working with strong and weak roofs and floors.
45. The Underground Arrangements in Collieries.
46. Modern Coal-washing, Coking and By-product plant.
47. The Influence of Coal-dust in contributing to Colliery Explosions.
48. The Drainage of Mines by Pumping and by Tunnelling.
49. The extent and effects of Subsidence in different circumstances by the Pumping of Brine in Cheshire and elsewhere.
50. The Methods of Gold-mining in California and other Countries.

51. The Occurrence, Production and Uses of (*a*) Asbestos, (*b*) Arsenic, and (*c*) Mercury.
52. The design, construction, erection and working of Modern Stamp Mills.
53. The Machines for Raising Mineral Tailings, as lifting-wheels, pumps, dredgers, etc.
54. Brine-pumping and the Manufacture of Common Salt.
55. Bessemer Converters and Reverberatory Furnaces.
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PREMIUMS.

1. The Telford Fund, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces a gross amount of £235 annually.

2. The Manby Donation, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The Miller Fund, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises nearly £140 per annum. Out of this Fund the Council has established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and is prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years. No Paper will be received from a Student

in competition for the Miller Scholarship and the Miller Prizes when he has become qualified by age, viz. twenty-five years, for election into the Corporation.

4. The Howard Bequest, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution. The annual income amounts to nearly £15. It has been arranged to award this prize every five years commencing from 1877. The next award will be made in 1902.

5. The Crampton Bequest of £500, free of legacy duty, has been invested in the purchase of £512 15*s.* 11*d.* $2\frac{3}{4}$ per cent. consols, and the income arising therefrom is now £13 14*s.* This trust is for the purpose of founding "a Prize to be called the 'Crampton Prize,' so that the interest of the said legacy shall be annually expended in a medal or books or otherwise . . . . for presentation to the Author of the best Paper on 'The Construction, Ventilation and Working of Tunnels of Considerable Length,' or failing that then on any other subject that may be selected."

6. The balance of the Trevithick Memorial Fund, amounting to £100 0*s.* 9*d.*, has been accepted for a periodical Premium to be called after Richard Trevithick. This sum has been placed in £103 $2\frac{3}{4}$ per cent. consols, upon which the interest is £2 15*s.* a year.

7. The James Forrest Medal, founded in 1897, is endowed with the balance of a sum of money given by those who had served on the Council towards a presentation to Mr. Forrest on his retirement from the Secretaryship. The medal is awarded annually to a Student of the Institution who contributes the best Paper received from that class.

8. The James Prescott Joule Medal is placed by the Trustees of the Endowment Fund at the disposal of the Council, in every third year, for award to a Student of the Institution, for the best Paper presented on an engineering subject, "preference being given to a Paper dealing with the transformation of energy." The medal will be at disposal next in 1903.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the premiums no distinction will be made between essays received from members of the

Institution or strangers, whether Natives or Foreigners, except in the cases of the Miller and the Howard bequests and the James Forrest and James Prescott Joule medals, which are limited by the donors.

Instructions for Preparing Original Communications.

In writing these Essays the use of the first person should be avoided. They should be legibly written on foolscap paper, on one side only, leaving a margin on the left side, in order that the sheets may be bound. Every Paper must be prefaced by an Abstract of its contents not exceeding 1,500 words in length.

Illustrations should be drawn on drawing- or tracing-paper, to as small a scale as is consistent with distinctness, and figured dimensions should be introduced only where necessary. When an illustrated communication is accepted for reading, a series of Diagrams will be required so drawn and coloured as to be clearly visible at a distance of 60 feet. These diagrams will be returned.

Papers which have been read at the Meetings of other Societies, or have been published, will not be accepted. According to the By-laws every Paper presented to the Institution is deemed to be its property, and may not be published without the consent of the Council.

The Communications must be forwarded to the Secretary, from whom any further information may be obtained. There is no specified date for the delivery of MSS., as when a Paper is not in time for one session it may be dealt with in a subsequent one.

James Forrest, *Honorary Secretary*,
J. H. T. Tudsbery, *Secretary*.

The Institution of Civil Engineers,
Great George Street, Westminster, S.W.
July, 1900.

Excerpt By-Laws, Article 3, Section XV.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. Except as hereinbefore provided, no person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

Notice.

It has frequently occurred that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors have advanced somewhat doubtful theories, or have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat that the Institution as a body must not be considered responsible either for the statements made, or for the opinions expressed in the Papers or in the consequent Discussions; and it must be understood that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the inquiry; but that such notice, or award, must not be regarded as an expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

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"Nature."
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North of England Institute of Mining and Mechanical Engineers.
Nova Scotian Institute of Science.

O.

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Pharmaceutical Society of Great Britain.
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"Phillips' Monthly Register."
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"Photogram, The."
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"Plumber and Decorator."
"Politecnico, Il."
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"Portfeuille économique des Machines."
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"Practical Engineer."
"Progressive Age."
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Q.

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Queensland Branch of the Royal Geographical Society of Australasia.
"Queen's Quarterly."

R.

Radcliffe Library, Oxford University Museum.
Railroad Commissioners of Massachusetts.
"Railway and Shipping Contractor."
Railway Commissioners of New South Wales.
"Railway Engineer, The."
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"Railways."
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"Revista de Obras Publicas," Lisbon.
"Revue générale des Chemins de Fer."
"Revue technique, La."
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S.

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Schweizerischer Ingenieur- und Architekten-Verein.
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"Shipping World."
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Société scientifique industrielle de Marseille.
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Society of Arts.
Society of Chemical Industry.
Society of Engineers.
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South African Philosophical Society.
South African School of Mines.
South Australian Railways Commissioner.
South Australian School of Mines and Industries.
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Spolku Architektů a Inženýrů v království Českém.
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"Steamship."
Stonyhurst College Observatory.
Street Department, Boston, U.S.A.
"Street Railway Journal."
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Syndics of the Cambridge University Press.

T.

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Timonoff, V. E. de.
"Tool and Machinery Register."
Townshend, B.
"Transport."
"Travelers' Official Guide of the Railway and Steam Navigation Lines in the United States, Canada and Mexico."
Trinity University, Toronto.

U.

Unione Tipografico - Editrice Torinese.
United States Artillery School.
United States Coast and Geodetic Survey.
United States Department of Agriculture.
United States Embassy.
United States Geological Survey.
United States Naval Institute.
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V.

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EXTRA MEETING.

23 April, 1900.

Sir DOUGLAS FOX, President,
in the Chair.

THE "JAMES FORREST" LECTURE.

The Chairman formally introduced the lecturer, Sir William Henry Preece, K.C.B., Past-President, who proceeded to deliver the eighth Address of this series as follows:—

"The Relations between Electricity and Engineering."

By Sir WILLIAM HENRY PREECE, K.C.B., F.R.S.,
Past-President Inst. C.E.

The nineteenth century is distinguished in our profession chiefly by the knowledge we have obtained of the constitution of *matter* and of the qualities of the materials we utilize for the service of man, of the presence and characteristics of that medium—the ether—which fills all space, and of the existence, indestructibility and protean character of that great natural source of force motion work and power which we call—*energy*.

Electricity is only one of many forms of this energy. It is measurable in well-defined and accurately-determined units. It is produced and sold, utilized and wasted. It is therefore something distinctly objective. It has even been defined by Act of Parliament.

There are four great principles underlying the practical applications of electricity:—

I. The establishment of a magnetic field.

II. The establishment of an electric field.

III. The disturbance or undulation of the ether.

IV. The work done by the generation and maintenance of electric currents in material systems.

It will smooth our journey over somewhat difficult ground if I commence by illustrating these principles with some elementary experiments.

1. *The Deflection of a Needle.*—A small magnet like that freely

pivoted in the mariner's compass is always forced into a position at right angles to a conductor maintaining an electric current. I am using energy from coal burnt in the electricity works in Millbank Street. It is brought into this building through conducting mains laid in pipes under the streets in its electrical form, and you see how its presence affects the needle. An electric current is not like currents of air, of water, or of gas. They are due to the flow of liquid or gas, and each current is confined to the interior of the pipe conveying the material. The so-called electric current affects not only the conductor that directs it but all the surrounding space, including any matter that it contains, and especially the ether that fills it. You have here evidence of the existence of a magnetic field—a field of force, of strain, and of motion. In fact, a *condition* of matter and the ether, and not a *form* of matter.

2. I take a portion of this conductor and wind it around a bar of soft iron. When the current is turned on the iron is impressed with magnetism. We have made an electro-magnet. Some of the energy of the electric current is transformed into its magnetic form, and we have powerful evidence of direction and stress—in fact, a magnified magnetic field. We thus get attraction, repulsion, and we are able to produce rotation and to strike great blows.

3. I take two coils of insulated wire, one of which I superimpose upon the other. I send intermittent electric currents through the one and insert a telephone in the other. A loud sound is emitted by the telephone, which gradually dies away as I remove the coils away from each other. The sound is restored in its loudness as I approach the coils together again. Here we have evidence of etheric disturbance. The electrical energy in the primary coil is transferred by waves through the ether and converted again into electrical energy in the secondary coil, appealing in its sonorous form to our consciousness through the ears.

This etheric disturbance is also the accompaniment of sparks in air. The sudden rupture of an air gap, the conversion of the air into a conductor, its immediate restoration to an insulator again, give sudden periodic undulations to the ether, which, owing to its inertia, sets waves in motion that extend to unknown distances. There is nothing but the air and the ether between me and that clock; yet I can control the movements of the clock by producing these sparks.

4. When I direct an electric current through acidulated water, the current breaks up the water into its constituent elements, oxygen and hydrogen; and if I insert a bar of white aluminium into a bath of blue sulphate of copper it is coated with a thin

layer of brown copper. The electrical energy does work upon the water and upon the copper solution, and we have ocular demonstration of the mechanical operations effected.

5. The work done by an electric current upon matter is still further shown by this platinum wire, which I can first make hot, then incandesce to redness, and finally fuse into drops with the evolution of brilliant white light.

We thus perceive that electricity is purely mechanical in its effects. It requires matter to render it evident to the senses. Its transference is characterised by motion, chiefly undulatory when we consider the ether, but partaking of the most known forms when considering conductors and insulators. It is therefore essentially a dynamical agent in the hands of the engineer to carry out his duties.

A. The Application of Force.—Electricity enables the engineer to direct energy to great distances, and there to apply force at his will. Force is that which produces, or tends to produce, motion. It is the function of the engineer to utilize this motion.

An electric current is by no means so simple a phenomenon as its name implies. The term itself is a survival of exploded doctrines. It is not alone the conductor that has to be considered but the whole circuit, especially its insulating portion, or dielectric, and the surrounding medium—the ether. The earth also frequently plays a very important and essential part. Moreover, the energy takes both the electric and magnetic forms, and one or other is dominant whenever the current is rising or falling or persistent. The rise and fall of lines of electric force produce a magnetic field, and *vice versâ*, the rise and fall of lines of magnetic force produce an electric field. In my experiments I converted this theatre into an electric and magnetic field, and if you possessed an electric sense you would have been conscious of unwonted disturbances. An *electric field* is that portion of space which is characterised by the presence of lines of electric force; a *magnetic field* by lines of magnetic force. Each line indicates the direction of stress, and the number of lines passing through unit area (one square inch or centimetre) the intensity of the stress. Matter through which they pass is in a state of strain; in conductors they produce currents; dielectrics are displaced electrostatically; magnetic substances, iron, nickel, and cobalt, are polarised electromagnetically. The motion produced is molecular motion—rotation, revolution, or oscillation. Lord Kelvin has very recently shown that an electrified body is set into rotation in one direction if positively excited, and in the other direction if negatively excited by the

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generation of a magnetic field around it, and that it will remain in rotation in virtue of its inertia during the existence of the field.

When the current is alternating it is always either rising or falling and changing its direction. The behaviour of alternating currents is more complicated than that of continuous currents, but both are subject to well-known conditions and to simple mathematical treatment. Each has its own particular sphere of usefulness. Some of the energy is wasted in the form of heat in the conductor, in the dielectric, and in the iron; some in the neighbouring conducting mains, and some is conveyed away—dissipated in limitless space. The ratio of the useful energy to that which is generated is known as the *efficiency* of the system. The steam-engine utilizes only 15 per cent. of the energy of the coal; the gas-engine utilizes 25 per cent. of the same energy; a turbine can utilize 80 per cent. of the energy of falling water; but the efficiency of a dynamo has reached the high figure of 98 per cent.

Alternating currents differ in their frequency. Those generated at Niagara pass through each cycle 25 times per second. The favourite frequency in the United Kingdom is 50, but many installations in the United States reach as high as 130. These frequencies in closed circuits can, however, be increased to millions per second in open circuits. In fact, Maxwell proved the identity of electricity and light by showing that they moved through the ether with the same velocity—196,400 miles per second—and in the same undulatory fashion. If the alternations could be generated with a frequency of 50 billions of waves per second we should see electric waves as light rays. Electric waves and light waves differ only in their length. Hertz detected and measured these electric waves. Attempts have been made to utilize them, but so far not with much practical success.

Whenever a conductor is forced through a fixed magnetic field so as to cut transversely the lines of force of that field an electromotive force is set up in that conductor which varies with the length of the conductor, the number of lines cut by it, and the rate at which they are cut. This is the principle of the *dynamo*. Work is done upon the conductor in moving it against the resistance of the field. Energy is thus transformed from its mechanical to its electrical form. At Niagara 5,000 HP. are converted by one machine into electric currents of 1,500 amperes driven by 2,200 volts.

If a conductor itself be free to move, and a magnetic field be projected through it while it is maintaining a current, it is forced into motion, and it becomes a rotating machine or *motor*. The electric energy of the current is transformed into its mechanical form. Its

torque, or turning moment, depends upon the intensity of the magnetic field, on the length of the conductor, and on the strength of the current. This reversibility of the dynamo is of immense commercial value. Maxwell said it was the greatest discovery of the century. Tramcars in our streets, trains on our railways, tools in our shops, and mills in our factories, are thus worked by electricity.

Dynamos and motors are subject to laws and conditions so thoroughly well known that exactness is assured and waste reduced to a minimum. There is no more perfect machine than a dynamo. Motors are nearly as good. Electricity as a science is fascinating to everyone, but it is deeply fascinating to the engineer. The reliability of its laws, the accuracy of its measurements, and the completeness and definiteness of the units to which its measurements are referred give him confidence in his estimates and a certainty of the performance of his preconcerted operations. It places in his hands the means of directing the energy out of sight in positions known only to himself, and of applying it with great efficiency at the exact spot desired. No magician or poet ever conceived so potent a power within the easy reach of man.

B. The Doing of Work.—The maintenance of an electric current through a conductor means the expenditure of work upon that conductor, and this expenditure of internal work means molecular motion. In solid conductors the result is *heat.* If the current be gradually increased, this motion is similarly increased. The result is successively incandescence, white heat, fusion, and disruption.

In liquid conductors the motion probably becomes revolution. The result is decomposition by the activity of the centrifugal force overcoming chemical affinity. The atoms fly away in fixed determined lines, and collect at opposite poles.

In gases the transference of electric energy in the form of sparks means dissociation. Compound gases are broken up into their component elements under the same directing influences. Work is done upon the gas as in the previous instances.

Joule established the law of the relations of current and heat upon a definite and accurate basis.

Faraday developed the laws of electro-chemistry with equal exactitude.

Professor J. J. Thomson has determined the action of currents on gases.

The principle of work that lies at the very root of the profession of the engineer enables all these operations to be measured in definite mechanical units, reducable to the common English

standard, the *foot-pound*, but which the electrical engineer, with greater precision, refers to the scientific unit of work—the *Joule*.

C. The Purification of Matter.—The elements and their useful compounds are rarely, if ever, found pure. Impurities have to be sifted away. Ores, raw produce, rocks, and earths have to be subjected to various processes of refining and conversion to extract from them that which is wanted. The electric current by the above operations has proved to be a powerful agent to break up crude materials into their useful and useless constituents. The electro-chemical industries of the world are very extensive.

According to Professor Borchers, the eminent electro-metallurgist, the world manufacture of calcium carbide for the production of acetylene gas is utilizing a power equal to 180,000 HP.; that of the alkalies and the combinations of chlorine for bleaching, 56,000 HP.; of aluminium, 27,000 HP.; of copper, 11,000 HP.; of carborundum, 2,600 HP.; and of gold, 455 HP. Electroplating is one of the staple industries of Sheffield and of Birmingham. There are nearly 200 firms working at the former place, and over 100 at the latter.

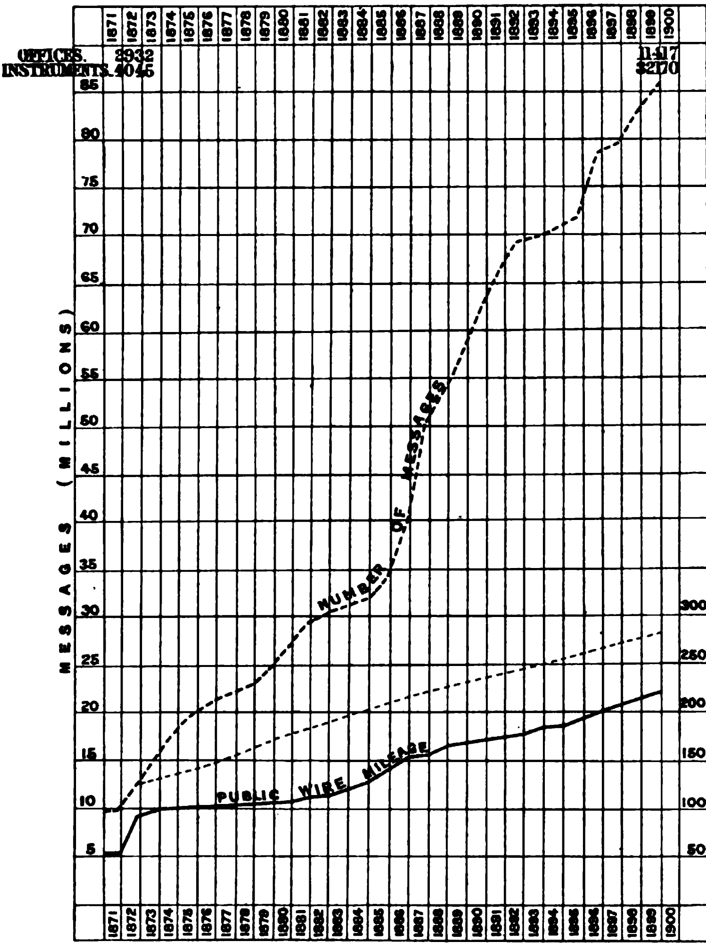
The decomposing bath and the arc furnace are revolutionizing many industries. Phosphorus is now being produced in England in large quantities from corundum, and aluminium from bauxite is extending in use and being reduced in price. The Post Office is using aluminium for telephone circuits. I have recommended its use on a very large scale in the interior of Africa, where transport is so costly. We can get the same conductivity as with copper with half the weight, and at a less price, and we can put up a line telegraphically ten times better than of iron for less money.

D. The Annihilation of Space.—The elements of Volta and the battery of Galvani—zinc, copper and a solution of sulphuric acid—gave a convenient generator of electric currents which could be directed along wires to great distances, and thus, by establishing magnetic fields, could deflect needles in such a way as to form the alphabet and so transmit words and, therefore, thought. In wires of great length, while the initial speed is that of light, it takes time for the electric waves to rise and fall, so that the number of currents which can be sent per second is limited. Between London and Liverpool the speed of speaking is virtually unlimited. but between Ireland and America it is restricted by the so-called *capacity* of the cable submerged in the ocean. This capacity absorbs energy and retards the rate of rise and fall of currents. While a thousand currents per second can be sent in the former case, only six per second are available in the latter.

Nevertheless, sitting on the shore of the Atlantic in Ireland,

one can manipulate a magnetic field in Newfoundland so as to record simultaneously on paper in conventional characters slowly written words. Thus we have bridged the ocean and annihilated

Fig. 1.



space. We do this on a smaller scale in our own domestic circles when we press a button and ring a bell in our servants' quarters. The sound of a bell and the drop of an indicator is a message—

NOTE.—*Fig. 1* indicates how engineering improvements have so increased the carrying capacity of wires that 200,000 miles of wire now do what it would have required 1,000,000 miles to do in 1871. The dotted line shows the number of mileages that the system at that period could have handled.

"You are wanted in the drawing-room." When the button is supplemented by the telephone, as it is in so many houses now, you can speak your message, "We want coals," and thus the servant is saved two journeys, and you have gained some time. Telegraphy is thus established in our homes. It becomes part of our daily life, not only in our domestic circles, but in our urban requirements and in our business relations. Not only is speech reproduced but handwriting also. Town is connected with town and nation with nation. London and Paris, Paris and Berlin, Berlin and Vienna, speak to each other with clearness and distinctness in ordinary language. The scattered British Empire is linked together. London and New Zealand are in communication with each other. All the world is joined in one unbroken whole, and we read on our breakfast-tables every morning the events of history made yesterday and the present condition of our friends in every quarter of the world.

The regulation of the ever-growing traffic on our railways and the safety of passengers is secured by similar means. The telegraph not only places the manager of the line in communication with every station upon his system, but electric signals control the motion of every train. Trains are kept apart by a considerable space. Collision would be impossible were the human will infallible; but the world is made up very much of fools and temporary maniacs. We all do at times what we ought not to do. The annual return of violent deaths is an interesting document. When in England alone 138 persons choke themselves at their own tables, and 765 die by falling downstairs, we must not condemn the railway signalman, who is responsible for the death of only 58 in 1898. A railway signal-box is an electrical exhibition. Every line is protected by its own electric signal. Every distant outdoor mechanical signal is repeated back. The danger signal is locked and cannot be lowered to "line clear" until it is unlocked by the train itself or by the distant signalman. Mr. F. W. Webb (Member of Council) is not only working the outdoor signals themselves by electrical energy, but he is moving the points and switches by the same means. So far the experience gained at Crewe during a period of about twelve months, from the working of a signal cabin containing about sixty levers, has been such as to justify confidence and the extension of the system, and some ten cabins containing about 1,000 levers will be provided. The apparatus has been designed to work in with as far as possible the standard signalling apparatus of the London and North-Western Railway. The interlocking frame may be said to be the ordinary mechanical frame in miniature, occupying one-third of the space. The levers

—about 6 inches in length—are placed in two tiers, and are manipulated in the same way as the levers of a mechanical frame, consequently the signalman accustomed to the old type has nothing to learn in the new. The levers are mechanically locked by means of tappet locking, and they control carbon switches by which the 110-volt electric current is transmitted to the motors.

The object of this electric working is primarily to reduce the manual labour of the signalman and enable him to pay more attention to the movements outside his cabin; increased speed of working; the removal of obstructions on the ground caused by the numerous wire and rod connections necessitated by the present system; and, finally, a reduction in the number of signalmen employed.

Thus electricity adds to the security of life. It supplies the railway man with a new sense and the engineer with a new power.

The abridgment of time necessarily follows from the annihilation of space, but the chief element which saves our time so much is the fact that we can, by electricity, do so much more from one spot. Indeed, in the United States the railway companies complained that their revenue between New York and Chicago suffered through the introduction of the telephone. People remained at home and did their business by wire.

It is very curious when visiting the United States to find that their morning papers contain extracts from our London evening papers of the same day. One frequently receives messages in England that were sent off to-morrow. This is due to the difference of longitude.

Wireless telegraphy, or, as it is better termed, etheric telegraphy, has made but small progress, owing to the simple fact that the demands for its services are so very few. There is no commercial business in it.

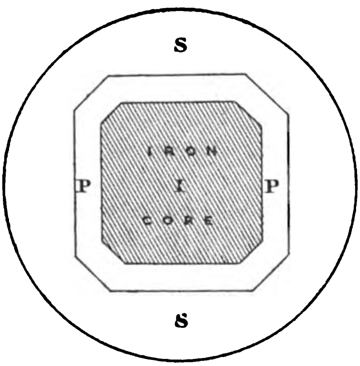
The fascination of electricity and the sensation of breaking down space by apparent magical means, have led to much gratuitous advertisement on the part of the press. I wrote in 1888, "The influence which electric currents exert on neighbouring wires extends to enormous distances, and communications between trains and ships in motion, between armies inside and outside besieged cities, between islands and the mainland, has become possible without the aid of wires at all by the induction, which is exerted through space itself."

The Post Office has for 16 years been developing this system. Several extensions are now in hand.

E. Transmission of Power.—The property that an electric current possesses of converting its environment into a magnetic field, and

the fact that the projection of a magnetic field through a conductor induces an electric current in that conductor, are prolific of many valuable instruments by which we transform energy into different intensities, and thus economise the cost of its transmission. The pressure that drives the energy through a circuit is called the *voltage*, the electrical form which this energy takes is sometimes called the *amperage*, and the resistance which the conducting part of the circuit offers to this flow of energy may be called the *ohmage*. There are other conditions that lead to waste, but these three conditions effect utility. The amperage by Ohm's law depends simply on the voltage and the ohmage, and the product of the amperage and the voltage, by Joule's law, gives the *wattage*, or the rate of expending energy usually called *Power*. The higher the voltage the smaller the amperage, and hence the less the weight of copper needed. The present practical limit of voltage along aërial conductors appears to be 40,000 volts. Beyond this pressure the dielectric strength of air breaks down. Higher voltages are practical in insulated mains, but their expense is a bar to their use.

Fig. 2.



It is not considered advisable to construct dynamos giving higher voltages than 2,500 volts, although in some cases 10,000 volts are produced; but these high voltages are easily and safely converted by transformers to any other higher pressures.

If I (*Fig.* 2) be an iron core made up of the thinnest and softest procurable iron sheets, and it be surrounded first by a primary wire maintaining the alternating currents at 5,000 volts; then if S be a secondary wire, having eight times the number of turns around the iron core that the primary wire has, then the voltage in the secondary circuit will be about 40,000 volts, setting up alternating currents of the same frequency, but of one-eighth the amperage. It would be exactly one-eighth if there were no waste of energy; but there is waste in the iron, the copper, and the air. Still the efficiency is very high, and frequently reaches 90 per cent.

Energy is also transformed in its continuous form by rotary converters, but in this case the process is usually the reverse. Direct continuous currents of 100 amperes and 3,000 volts are reduced to 500 volts by acting as motors to rotate generators,

giving 600 amperes, for, say, tramway working. Again, at Tivoli, 18 miles from Rome, the energy of the falling water there is transmitted to Rome in the form of alternating currents at 6,000 volts, and is there converted by rotary transformers into direct currents at lower voltages for battery, traction, and motive purposes.

The sun is the *fons et origo* of all the available energy upon the surface of the earth. Coal and oil are extracted from the earth's crust; oxygen is found in its atmosphere. Grasses, corn, fruits, and vegetables become food and fuel for beast and man. Waters are converted into vapour, forming clouds, rain, brooks, rivers, torrents, and falls. The atmosphere is disturbed by wind, and the waters of the ocean by tides. Energy is thus found available for useful work in many different forms. The problem before the engineer is how to select the best form of energy for his purpose and how to utilize these waste energies of Nature so as to secure the best economical result. Falling water can, by a turbine or impulse wheel, convert the energy it possesses in virtue of its fall into the form of electricity. By the aid of transformers it can be raised to very high voltages; 40,000 volts is employed in California, 11,000 in Niagara. We use 10,000 between Deptford and Trafalgar Square. It can thus be transmitted to any reasonable distance, and there it can be utilized to do useful work. The waste forces of Nature are thus within our reach. The waterfalls of the Highlands may work the tramways of Glasgow; Niagara already works those of Buffalo.

The economy of this system for large industries is a question of the relative cost of the generation of energy by other means. Energy on the coal-fields can be produced cheaper by burning coal than by any water scheme that I have yet examined in this country. The price and abundance of coal renders the transmission of energy to great distances at present a very limited question indeed. Where coal is scarce and dear and water abundant, as in Switzerland, water-power is very much utilized. Where coal is abundant and cheap, as in England, it is often uneconomical to adopt it. The transmission of power within limited areas by electricity in our cities is now within the range of practice. In Edinburgh it is supplied at the rate of 1½*d.* per unit; this is 0·83*d.* per HP.-hour. It is invaluable for small industries. It is there ready to be used when it is wanted; it wastes nothing while idle.

The economy and efficiency of distributing power over mills, factories and workshops by electricity instead of by shafting, gearing and belts, is so pronounced that the change is being effected in every country with great rapidity. If it were a

question of the mere efficiency of the two systems, the advantage of the change would not be so obvious; but it is shown by the HP.-hours expended, which means the coal bill. The efficiency of an electrical system is rarely less than 75 per cent., while that of shafting is frequently as low as 25 per cent.; it is the continuous waste of the latter that tells on the coal bill, while in the electrical system there is no such waste. The motor runs when it is wanted, and expends only what energy is wanted for the particular work to be done. Electrical measurements are so exact and so easily applied that automatic records can be obtained of the work done by each machine. Hence its economy.

Every up-to-date workshop should have its electric plant for healthy light, cheap power and handy distribution of material. Its economy is demonstrable in the smallest, but in the largest shops it is at once most marked. It is always available and it costs little. Ignorance or timidity restricts its use very much. The number of works that are run by electric motors in different parts of the country is very large indeed. The efficiency, handiness, and economy of doing so is so marked that the practice is extending with great rapidity. Motors themselves are being daily improved.

We underrate very much the progress made in the United Kingdom in different industries, owing to the secretiveness of the British manufacturer. He will not report what he is doing in the press, and the press leaves him severely alone. Electricity as an economiser, by increasing the speed of output and by reducing waste, is as much at the disposal of the British as of the American manufacturer. But John Bull clings with affectionate and conservative fervour to the capital expended by his grandfather, while Uncle Sam does not hesitate to throw obsolete plant on the scrap heap, if, by doing so, he can increase his business. Progress in the States is also not so seriously checked by Trades Unionism as it is here. I am told that the Bricklayers' Union in England limits a man's daily work to laying 400 bricks, while in the States he does 1,200! This limiting of the output of labour is a much more serious tax on the nation than a war tax. It drives trade out of the country, it restricts the intelligence and lowers the tone of morality of our working classes. It is a disease to be grappled with.

On the Clyde and the Tyne, and indeed wherever shipbuilding is flourishing, there we find electrical energy driving machine tools, holding up plates, and assisting in various processes. In many large machine works cranes and travellers are moved by it.

At Boston, U.S.A., crossing the Charles River and uniting Charlestown, the scene of the famous Battle of Bunker's Hill,

with its head-quarters, is a new bridge 100 feet wide and 1,920 feet long, having a draw of 240 feet span, weighing 1,200 tons. This draw is opened and closed by electric motors.

In the Post Office we have introduced electric motors very largely. At Leeds they are used for driving pneumatic pressure and vacuum pumps, employed there to work the pneumatic tube system. They are also used for working automatic stokers, ventilating fans, and lifts.

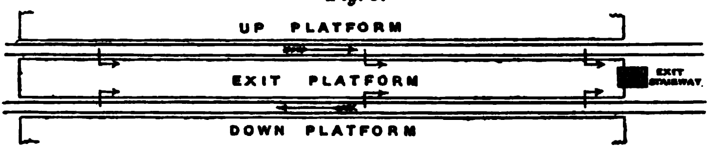
F. Traction.—It is for traction purposes that electricity is making such gigantic strides. In the United States tramway working by its means has become practically universal. In the United Kingdom it is making rapid way, and in connection with electric lighting it is giving great economical results. The combination of the two systems is most effective. At St. Helens, in Lancashire, where 13,435 8-c.p. lamps are connected, and a small tramway system of nine cars simultaneously running is at work, the works costs have been brought down from 3·23*d.* per unit to 0·67*d.* per unit. The price for electric light has been reduced from 6*d.* to 4½*d.* per unit, and it will probably be lowered to 3½*d.* This is after only 8½ months' working. St. Helens is an object lesson to all municipalities, especially to Glasgow, where a very false start has been made.

Electric railways are also growing apace. A bold attempt is being made by the Metropolitan railways to work the existing line in such a way as not to interfere with the existing traffic or even with the permanent way. A new train of six coaches weighing 180 tons, having a motor car at each end weighing 54 tons, is about to run between Earl's Court and High Street, Kensington. Each motor car is mounted on bogies, and each bogie has two electric motors, so that there are eight driving wheels, each bearing 6·75 tons. The driving wheels have diameters of 47 inches. The length of the train is 240 feet. Each motor is rated at 200 HP., or a total of 800 HP. for each motor car. But there is a wide margin, and we have already applied 950 HP. in starting a load of 270 tons on the incline of 1 in 43. Electric traction has an immense advantage over steam traction in impressing a continuous and uniform torque or turning moment on the shaft, and consequently a continuous and uniform effort on the tread of the wheel. The action of the steam locomotive is intermittent and the bite not continuous. Hence such frequent slipping on greasy rails. Again, the maximum torque can at once be applied by the current, and, in combination with the constant effort, it increases the acceleration so that a train acquires its maximum speed much more quickly. We shall increase the mean speed of the

metropolitan trains from 11 miles per hour to 15, and thereby increase the capacity of the line over 30 per cent. The stoppages on the underground railways are so frequent that the trains are always either accelerating or stopping. They never reach their top speed as they do on main lines. Electric traction enables them to start quicker and stop more promptly. On the Metropolitan the 180-ton train acquired 20 miles an hour in 200 feet, and, when going at the same speed, it was stopped in 130 feet—half its length. Smart work on such a railway depends on the rate at which trains can be emptied and filled. The English system of compartments and side doors facilitates this. It would be still further expedited if we could have one platform for entry and one for exit, and one class only (*Fig. 3*).

The Liverpool and Manchester Lightning Express Railway, promoted by a very powerful representative syndicate of those two great commercial centres to carry out the scheme of Mr. Behr, is a very bold and promising venture. The line is to be monorail, 34 miles long, direct between the two cities, without any inter-

Fig. 3.



mediate station and with no crossing. There are to be cars every 10 minutes. The speed is to be 100 miles per hour, and the time of transit 20 minutes. I know of no reason why this should not be done with safety and comfort.

The automobile car of the future has not yet seen the light. It will be electrical. Immense progress has been made in motors and in batteries. Lundell has shown how to store up the energy now wasted in descending hills, and to recover some of that absorbed by the inertia of the car. Although a battery has already been able to drive a car 100 miles with one charge, we are waiting patiently for the real automotor storage cell.

G. Electricity in War.—A strong contingent of electrical engineers has volunteered for service in South Africa. They are all scientifically-trained practical young engineers. Bicycles, field telegraphs, telephones, arc and glow-lamps, cables, search-lights, traction-engines and generating plant will be under their care. It is strongly hoped that we may soon hear good accounts of their performances at the front. They are under the command of Major Crompton, a Member of the Institution and an old soldier.

Electricity has been extensively applied to the development and utilization of explosives in both the civil and military divisions of our profession. Charges are safely fired under water and blasted in mining and demolition operations by small exploding dynamos, magnetic-electric machines or induction coils acting upon high tension fuses. Our Honorary Member, Sir Frederick Abel, has especially distinguished himself in this direction. His fuse, composed of phosphoride and subsulphide of copper, is universally used by our War Department. Time guns are thus fired at stated hours at different sea-ports by currents originating in Greenwich Observatory. Broadsides in battle-ships and guns in turrets are similarly discharged. Torpedoes are even directed by currents from the shore. The defence of our coasts by submarine mines and their explosion by currents when the enemy's ships are properly located by position-finders is the last development of the application of electricity to war.

Electrical blasting has revolutionized the operations of tunnelling and driving galleries. It is much used in quarrying with great security to the men. The deepening of harbours and channels and the removal of obstructions such as wrecks and rocks are facilitated. On the 23rd September, 1876, 63,135 cubic yards of solid rock were completely demolished by one discharge at Hell Gate in East River, New York. The preparation for this great blast took 4 years and 4 months. There were 4,427 charged holes, each containing its mercury fulminate fuse and charges of dynamite. There were 49,914 explosions used in that one blast. Batteries were used to generate the currents, and they were arranged in large groups. Each battery exploded 160 charges. This was the record blast.

The battle-ship is the home of electricity. It controls the rudder, it ventilates the interior and the living space of the ship, it forces the draught and assists the raising of steam, it revolves the turrets, it trains and controls the fans, it handles the ammunition, it purifies the drinking water, it lights up the ship internally, it enables the captain to sweep the horizon with the brilliant rays of the search-light, and to communicate with his tender or with his commanding officer across space independent of weather, night, season, fog or rain.

H. Sanitation.—No branch of our profession fulfils the true function of the engineer more efficiently than that which deals with sanitation. Pure air, pure water, pure food, pure soil, pure dwellings, and pure bodies are the panacea for health and comfort. Electricity helps us very much in attaining some of these qualities. An electric glow-lamp does not vitiate the air. It does not throw

into circulation in the air any product of combustion. The question of ventilation is very much reduced in importance and rendered more simple to effect. Much less air need pass through our sitting-rooms and meeting-places. The air vitiated by our lungs can be easily withdrawn and fresh air can be forced in by fans worked by electric motors. Even the air during its entrance can be warmed, and impurities floating in it can be sifted out of it by the attraction of electrification.

Heating by Dowsing's luminous electric radiators is very much on the increase; they consume 250 watts, which cost about ½*d.* per hour.

In many post offices sealing wax is melted and kept in a liquid state by currents.

Water can be sterilized by ozone, a product of electrification, and even by the nascent oxygen, when broken up into its constituent elements by electric currents.

Sea-water thus electrolysed supplies us with chlorine, and converts the water into a powerful antiseptic, disinfectant, and deodoriser. Its economy is, however, doubtful, and in consequence its adoption has been much restricted.

I. Industries.—The applications of electricity to other industrial processes are innumerable. I have time to mention only one. Mr. T. A. B. Carver, B.Sc., who was a pupil of Lord Kelvin and an officer on our Staff in this Institution, has brought out a new Jacquard loom for weaving; 600 hooks are controlled electrically. The twill as well as the pattern is under complete management. It has been warmly taken up in Glasgow, and a factory has been started there.

The pattern on this cloth is woven directly from a photo-print of the artist's design, mounted on a metallic sheet. The threads of the warp are picked up by electromagnetic action, owing to the figure of the pattern being cut away, and thus allowing the circuit to be completed by the metallic sheet.[1]

The theme of the relations between electricity and engineering is too great for an hour's discourse. Electricity tends to economise labour and to cheapen the cost of living. It increases national wealth and promotes international friendship. It enlightens the invisible and it alleviates suffering. It conduces to avert war and

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[1] The Lecturer exhibited a piece of damask, on which had been woven by this means a short time before the lecture the following words:—

The Institution of Civil Engineers.

"JAMES FORREST" LECTURE, 1900.

By Sir W. H. Preece, K.C.B., Past-President.

it certainly facilitates the conclusion of peace. Its practical applications have run *pari passu* with our revered Queen's reign. They are growing with great rapidity. Who can forecast the future? One simple lesson that I have learnt is that in the practical developments of electricity the only thing that occurs is the unexpected.

There is now a distinct line of demarcation separating the physicist from the engineer. The former dives into the unknown to discover new truths; the latter applies the known to the service of man. Research is the function of the one; utility that of the other. In the past the engineer had to rely on himself for his facts, but the advance of modern science, the growth of technical education, the formation of Laboratories, and the endowment of Chairs have changed all that.

We can scarcely hope for new sources of energy to be discovered, but there are some existing ones we have not touched yet. When the evil day arrives for our coal supplies to give out we may perhaps be able by the aid of electricity to utilize the heat of the sun and the tides of the ocean. There is, however, a vast illimitable store of energy not only in the rotation of the earth upon its axis, but in the internal heat of this globe itself. As we descend, the temperature gets higher and higher. It ought not to be difficult to reach such temperatures that by thermo-electric appliances we might convert the lost energy of the earth's interior into some useful electric form.

The CHAIRMAN moved a hearty vote of thanks to Sir William Preece for his most interesting lecture, and mentioned that a collection of electrical appliances was on view in the Library.

Sir FREDERICK BRAMWELL, Bart., Past-President, seconded the vote of thanks with great pleasure. The lecture was most interesting and suggestive as to the uses which had been made and that might be made of electric energy. He was tired of hearing persons who had travelled exclaim how much behindhand we were in England in electric matters, and of listening to their statements that small villages in Italy or Germany had long been electrically lighted, while we were only beginning, as it were. He asked these persons if they knew the reason? No; they supposed it was due to our national inertness. He suggested to them that some years ago, in 1882, there was an Act passed, facetiously called "An Act for the Promotion of Electrical Undertakings." The effect of the Act was that if anybody embarked his capital in an electrical undertaking, and should the municipality, after 21 years, want to buy it, he must give it up to the municipality

without any compensation for past or future profits, and must be satisfied with payment for the then mere value of the materials, whatever that might be. There was a further provision, that, if at the end of 21 years the municipality did not choose to buy the undertaking because it did not pay, then, at the end of 7 further years, the option of purchase would re-arise, and so on from 7 years to 7 years. That was, as long as it did not pay the owners might keep it, but when it began to pay they must give it up. When he mentioned these things in the United States, he was treated with incredulity on the ground that it was impossible there could be such a law in a civilized country. It was, in his opinion, a fraudulent Act, and one of the greatest mistakes ever made. That was what electricity had suffered under in this country. He could not help delivering himself of those feelings which had been burning within him for a long time. He had great pleasure in seconding the vote of thanks.

The motion was carried by acclamation.

Sir WILLIAM PREECE said he was very grateful for the kind way in which the members had received his effort to meet the wishes of their great friend, James Forrest, by taking up some branch of science and showing its application to the work of the Institution. It was but natural that he should take up his favourite science, one in which he had been an earnest and hard worker for nearly 50 years. He did not agree with Sir Frederick Bramwell's remarks about the Act of 1882, but thought he would not be right to take advantage of a short speech in returning thanks to enter into a discussion on the subject. He thanked the members very much for the vote they had just passed.

The preceding lectures of this series have been :—

Date.	Subject.	Author.	Proceedings Inst. C.E. Volume.
1893	"The Interdependence of Abstract Science and Engineering".	Wm. Anderson, D.C.L., F.R.S.	cxiv.
1894	"Relation of Mathematics to Engineering"	John Hopkinson, D.Sc., F.R.S.	cxviii.
1895	"The Development of the Experimental Study of Heat-Engines"	Prof. W. C. Unwin, B.Sc., F.R.S.	cxxii.
1896	"Physical Experiment in Relation to Engineering".	Alex. B. W. Kennedy, F.R.S.	cxxvi.
1897	"Bacteriology"	G. Sims Woodhead, M.D.	cxxx.
1898	"The Relation of Geology to Engineering"	Prof. W. Boyd Dawkins, M.A., F.R.S.	cxxxiv.
1899	"Magnetism"	Prof. J. A. Ewing, M.A., B.Sc., F.R.S.	cxxxviii.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 3208.*)

"Consolidation Works on the Palermo-Corleone Railway."

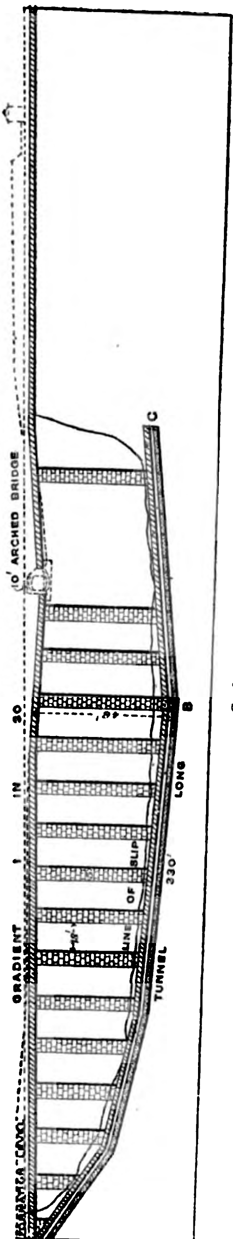
By ROBERT JARRATT MONEY, Assoc. M. Inst. C.E.

THE Palermo-Corleone Railway, 40 miles in length and of metre gauge, is a mountain railway running from Palermo, the capital of Sicily, southwards to Corleone. The interior of the island consists of lofty ranges of hills, over two of which the line is carried, climbing up the slopes by steep gradients and sharp curves; 30 miles of the railway are on a gradient of 1 in 66 or steeper, of which 6 miles are on the maximum gradient of 1 in 25. At its commencement the railway skirts the bay of Palermo for 4 miles, and then turns inland and commences to rise, until at 26 miles it has attained its maximum elevation of 2,400 feet. Except for 3 miles through a forest, the line traverses cultivated land, part bearing grain and the rest being vineyards. The absence of trees, and the method adopted of heaping the soil round the vines into a saucer-like form to retain the rain for purposes of irrigation, assists the causes producing the slips from which this railway, in common with most of those in Sicily, has suffered.

A large amount of the material moved in constructing the banks and cuttings consisted of argillaceous marl, which occasioned considerable trouble and a heavy expenditure for maintenance. After the line had been opened for traffic, extensive works for draining and drying the land in the vicinity of the railway, and minor works for draining and drying the slopes of cuttings and banks, had to be undertaken. These are known locally as "Consolidation Works," and are a feature in all railway construction in Sicily.

The greater part of the railway is located on steep side-lying ground, and the ordinary difficulties in dealing with ground composed of argillaceous marl are here increased by the nature of the climate, the absence of shade, and the method adopted to irrigate the vines. A long and intensely hot summer is followed by heavy rains. The ground, parched by the heat, opens into

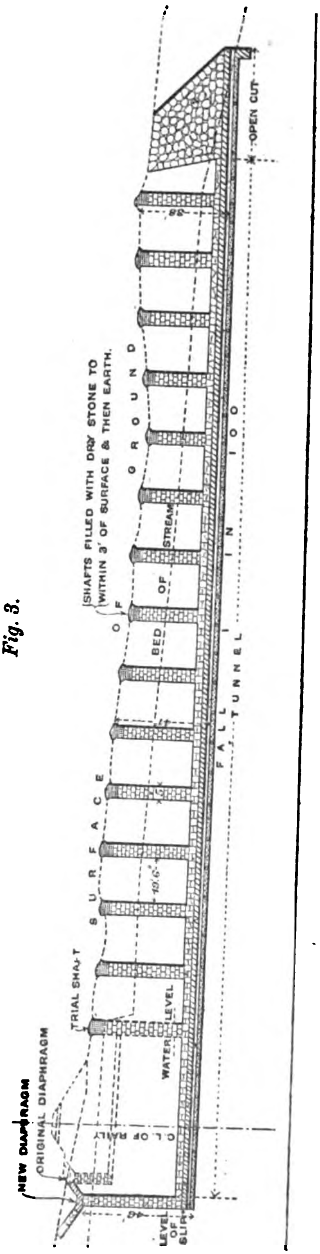
Fig. 2.



Scale, 1 inch = 32 feet.

LONGITUDINAL SECTION OF DIAPHRAGM, A B C.

Fig. 3.

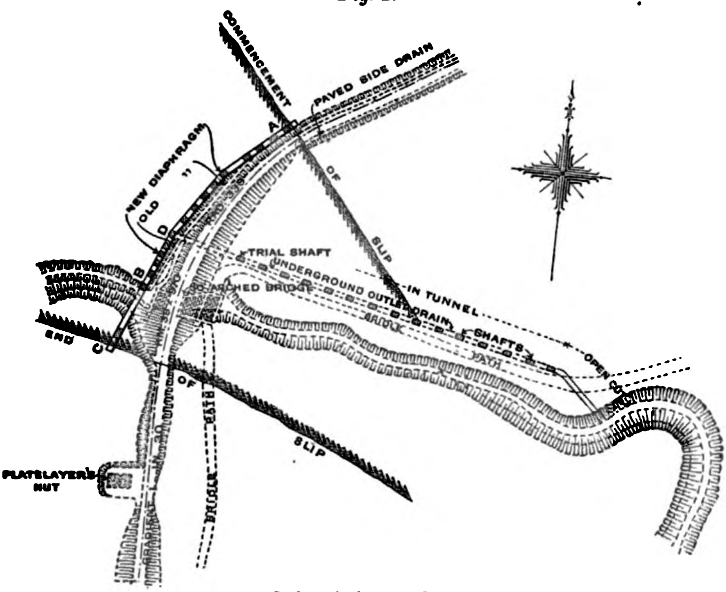


Scale, 1 inch = 32 feet.

LONGITUDINAL SECTION OF OUTLET-DRAIN, D E.

rains beyond stationing at this point an extra gang of platelayers, whose duty was to keep the road open for traffic. As soon as the bridge showed signs of cracking, it was strutted with stout timbers, and, as it moved down the hill, the permanent way was thrown back to its proper position. Immediately the dry season set in a trial shaft was sunk to ascertain the nature of the ground, the water-level, and the depth of slip. As the cracks marking the boundaries of the slip continued a long way up the hillside, it was at first decided to put in a diaphragm A B C, *Fig. 1*, with an outlet-drain D E

Fig. 1.



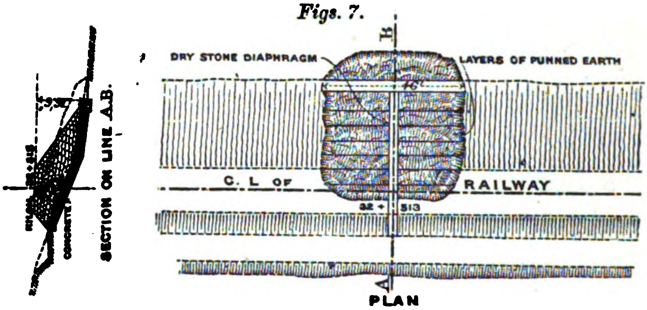
Scale, 1 inch = 200 feet.

Godrano Slip Consolidation.

running into the stream from the 10-foot bridge. A small diaphragm already existed, but it had not been carried deep enough to be of use. The foundation for the new diaphragm was executed by means of sixteen shafts, 18 feet apart from centre to centre and 5 feet by 3 feet 3 inches in section, connected at the bottom by a tunnel 6 feet 6 inches by 3 feet 3 inches in section, *Fig. 4*. The excavation was sunk 3 feet below the line of slip so as to come on to a hard and impermeable bottom. On this a drain was laid formed of concrete 2 feet 3 inches thick, dished in the centre to form a channel 16 inches deep and 14 inches wide for the water,

right through the slip into the solid. Generally, underneath the steps a layer of concrete between 4 inches and 6 inches thick was placed, projecting 6 inches beyond the spur below. The lowest step

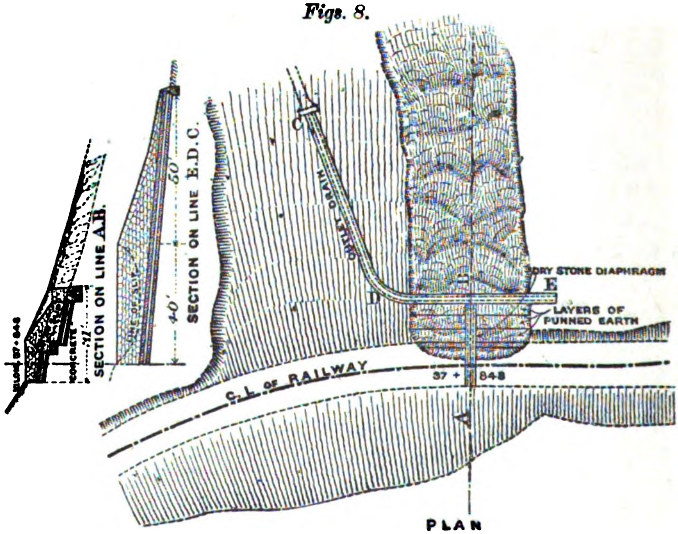
Figs. 7.



Scale, 1 inch = 64 feet.

having been filled up, a layer of concrete was placed on the second, projecting 6 inches over the dry stone filling in the step below, so that there might be no scour at the back of the steps, which have a fall outwards of about 1 in 20, *Fig. 6.* In cuttings, the toe B

Figs. 8.

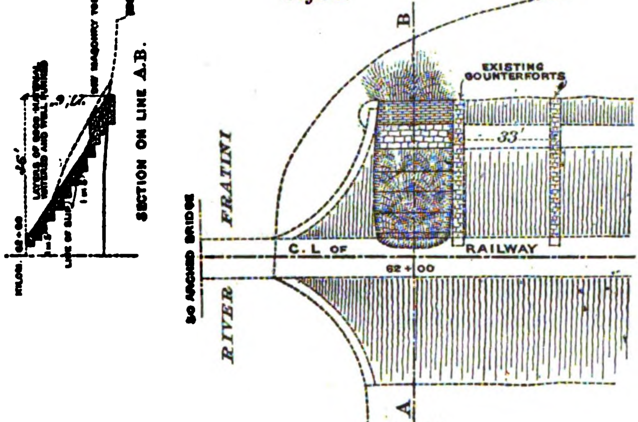


Scale, 1 inch = 64 feet.

was generally kept high enough to discharge the water collected into the side drains of the railway; but where it was necessary to carry the spurs below formation-level, a second masonry drain was constructed below the side drain, at such a depth as to collect

the water discharged from the spurs, with an outlet, or outlet drains, running under the railway at right angles to the centre line. When these counterforts were insufficient to prevent the

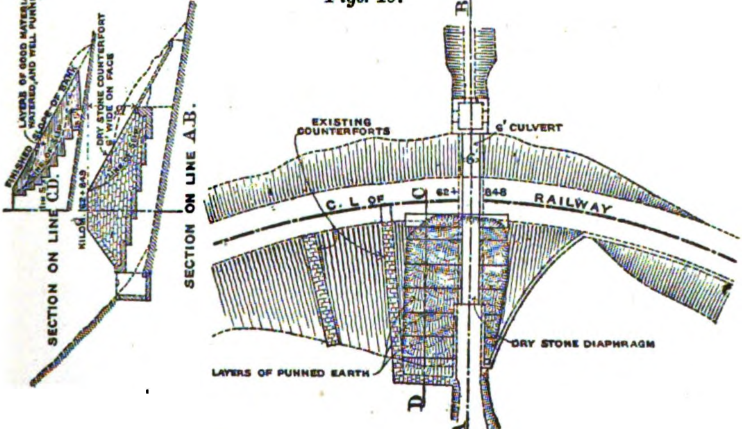
Figs. 9.



Scale, 1 inch = 64 feet.

slopes from slipping, the whole of the material in the slip was removed and replaced between the counterforts by good material,

Figs. 10.

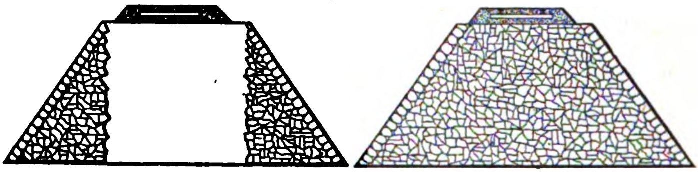


Scale, 1 inch = 64 feet.

in layers between 12 inches and 16 inches thick, watered and well punned. In banks the foundation was cut into steps sloping inwards on a gradient of 1 in 5, *Figs. 7–10.*

In consolidating banks made of bad material, the counterforts were frequently carried right up to formation-level, and instead of being stepped up on the inner side were vertical as in (*a*), *Figs. 11.* In cases of very bad material, the spurs were carried right

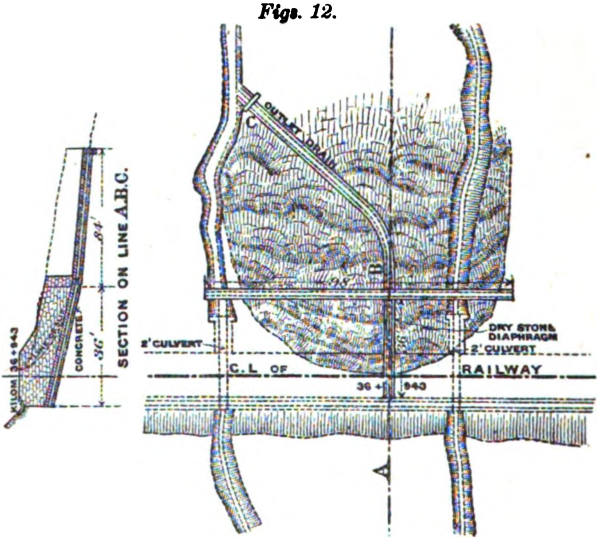
a *Figs. 11.* *b*



through, and thus, besides draining the bank, helped the material to support itself and the weight of the train above, (*b*), *Figs. 11.*

Aprons.—If the water collected by the masonry drains was merely carried clear of the railway and then discharged on the

Figs. 12.



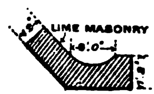
PLAN.
Scale, 1 inch = 64 feet.

steep hillside, it quickly cut a channel which rapidly increased in size, until it became a deep ravine. It was necessary, therefore, to pay great attention to all water-courses, and to carefully guard against scour. In the larger streams this was effected either by paving the channel, or by aprons in the bed and toe walls as a protection to the bank.

In the case of a rapid fall, a well was built on the lower side of the apron to act as a cushion; this answered satisfactorily. At the entrance to culverts similar wells were provided, to act as cushions and to catch the soil washed down and prevent it blocking up the entrance wherever a stream with a rapid fall discharged into a culvert.

Toe Walls.—A slip in a 30-foot bank, caused by the scour of a river at the foot, is shown in *Fig. 9*. Here, owing to exceptionally heavy rains, the river scoured away the solid ground on which the bank was built, and began to work behind the wing wall of the bridge. Further damage from the river was stopped by throwing rock into the hole scoured out at the foot of the bank, and behind the wing wall; and, as soon as the dry weather set in, by building a dry masonry wall. The slip was repaired by cutting steps in the bank, sloping inwards on a gradient of 1 in 5, parallel with the centre line of the railway and passing completely through the slip, and replacing this by good material in layers between 12 inches and 16 inches thick, watered and well punned.

Fig. 13.



Scale, ¼ inch = 1 foot.

Side Drains in Cuttings.—Different sections have been adopted on the Sicilian railways. That shown in *Fig. 13*, gave the most satisfactory result on the Palermo-Corleone Railway. It was easily cleared of the material washed down the slopes, and was the least expensive to maintain. It was built of masonry in lime. In bad ground a foundation of dry stone was first laid as shown in *Fig. 5*.

Drains on the tops of Cuttings.—These were provided along the tops of all cuttings. After the line was opened, the sides in many cases fell in, and it was found necessary to replace them by masonry works. These were of two kinds: (1) Ordinary cut-water drains built in lime masonry to the section shown on the top of the diaphragm in *Fig. 5*; (2) When the above were insufficient to dry the ground and prevent slips a masonry diaphragm was inserted. If the slip was shallow, it was sufficient to place the diaphragm 5 feet from the top of the cutting; when the slip was deep the diaphragm was placed at a distance of about 33 feet from the top. This diaphragm was always founded at least 2 feet 6 inches below the bottom of the slip, and was built with a bottom drain, and with a channel on top, of the section shown in *Fig. 5*. The side wall of the bottom drain was built of dry rubble on the uphill side, while that on the downhill side was built in cement masonry.

Planting.—Were it not too slow in operation the most effective

means of draining and drying the ground would be by planting suitable vegetation. Good results were obtained from acacia, eucalyptus, and Hottentot's fig (*Mesembryanthemum edule*). Acacias not only drained the ground, but the shade of their thick foliage moderated the evil effects of the fierce sun in causing cracks in the ground. Eucalyptus, owing to its long deep roots, proved effective in draining a marshy site. It was planted round unhealthy stations and wherever malaria existed. A marked improvement in the health of employees was noticeable after the trees had been planted one year. Unfortunately their delicacy and extreme sensitiveness to frost are against their employment in many places. The Hottentot's fig, planted on slopes, gave good results in conjunction with masonry and other consolidation works. A peculiar feature of this plant is the absorption of moisture by its leaves; and when the ground is covered by a thick growth of it, a good deal of the rainfall never enters the soil.

In addition to the remedies already described, all large cracks above the tops of the cuttings were carefully filled in and made good towards the end of the dry season. *Figs. 7* and *10* show slips in the slope of a bank, which were repaired by inserting a diaphragm right through the bank to collect and carry off the water, removing the material that had slipped, and replacing it by good material in layers 12 to 16 inches thick, watered and punned.

In *Figs. 8* and *12*, as the slips tailed out for some distance, a dry stone wall, parallel to the centre line of the railway, was inserted in addition to a diaphragm, to cut off from the slip all water flowing from the hillside of the railway.

Cost.—The average daily wages paid were:—Excavators, 1*s.* 6*d.*; labourers, 1*s.* 8*d.*; masons' labourers, &c., between 1*s.* 10*d.* and 2*s.* 1*d.*; masons, between 2*s.* 6*d.* and 3*s.* 4*d.*; stone-cutters, 3*s.* 4*d.*; and the average cost of the consolidation works was as under:—

Maximum Height of Bank or Depth of Cutting.	Cost per Lineal Yard of Railway Consolidated. £	s.	d.
Between 3 feet 3 inches and 33 feet	11	13	0
„ 33 „ „ 49 „	22	17	0
„ 49 „ „ 65 „	38	3	0
„ 65 „ „ 98 „	56	9	0

In conclusion, the Author desires to acknowledge the assistance he has received in the preparation of this Paper from Mr. F. Calandra, who acted as his Resident Engineer on these works.

This Paper is accompanied by two tracings, from which the Figures in the text have been prepared.

(*Paper No. 3185.*)

"Design and Construction of Steel Bridge Work, with Particulars of a Recent Example in Queensland."

By Clements Frederick Vivian Jackson, B.E., Assoc. M. Inst. C.E.

In the preparation of a complete set of working drawings for the construction of a railway bridge, perhaps those which call for the greatest ingenuity of arrangement and mathematical exactitude on the part of the designer are the detail drawings of the framed steelwork; on his accuracy and on the economical distribution of material depend the security and the cost of the finished structure.

In making the calculations for the purpose of proportioning the various members in a bridge-truss of given span the forces chiefly to be considered are those due to its own dead load, to the wind pressure, and to the rolling load, the latter including secondary stresses developed at the joints. For the purpose of illustrating some methods adopted in arriving at these stresses, and, where of special interest, the principles underlying them, it will be convenient to describe the actual design of a recent work, and the aim of this Paper being to discuss both design and erection of steelwork, a suitable example has been selected in the Burdekin Bridge. It will not be possible, however, to consider every step in detail; hence in such calculations as those for finding the strength required in the floor-beams, etc., it has been considered sufficient to merely illustrate the method by which the position of the engine for maximum effect on the beams is arrived at.

The Burdekin Bridge, which has just been completed, is the first of its type built in Queensland. The plans were completed in the office of the Chief Engineer for Railways (Mr. H. C. Stanley, M. Inst. C.E.) in April 1896, and the contract for construction was signed on the 1st May in the same year, the amount being £72,971, which included the cost of constructing about 2½ miles of approaches over easy country. The Burdekin River

has a drainage area of 14,000 square miles above the site of the bridge, the total drainage area being 55,530 square miles. It is only navigable for a few miles, and the site of the bridge is 90 miles from its mouth. The highest recorded flood occurred in the year 1870 with a rainfall of 15·8 inches, which gave a cross-sectional area of 81,244 square feet occupied by flood-water, the observed surface velocity being 9 miles per hour.

The site of the bridge on the main railway-line from Townsville extends between 70 miles 67½ chains and 71 miles 24 chains, a total length of 2,414 feet. The new bridge is essentially a high-level bridge, built to supersede the former low-level bridge, which, being designed to allow flood-waters to pass over it, was consequently a source of great delay to traffic during the rainy season. The high-level structure is designed to carry a single line of the standard gauge of the colony (3 feet 6 inches), and the prominent features consist of six 250-foot openings, spanned by double-intersection Whipple-trusses with riveted connections, two 40-foot concrete arch-abutments, continuous girder approaches, each 200 feet long, carried on cast-iron columns 50 feet apart, and 434 feet of timber trestle-work at the eastern end to carry the line from the bank to the continuous girders, Fig. 1, Plate 8.

Having regard to the most economical span and the governing local conditions, it was decided to make the trusses 246 feet in length between the centres of bearings, the other dimensions being, depth 30·75 feet and panel length 15·375 feet, the trusses being placed 15 feet apart, Fig. 2, Plate 8. The design of deck adopted is indicated in Fig. 5, Plate 8. This, with the cross girders attached to the posts above the lower chord, forms the best arrangement for this class of work. The stringers are proportioned for their own weight, their dead load, and the standard engine-load used for deck work. This engine-load is shown in Fig. 6, Plate 8, in the correct position for giving the maximum bending moment in the stringers. It will be seen that wheel No. 3 is placed 0·8 foot from the centre of the beam; in this position it satisfies two conditions, viz.:—

(1) The average load per unit length to the left of wheel No. 3 is equal to the average load per unit length on the whole beam.

(2) Wheel No. 3 is as far from one end of the beam as the centre of gravity of all the loads on the beam is from the other end.

That these are the two governing conditions may be demonstrated as follows: In Fig. 7, Plate 8, let w_1 be a single force replacing all the wheel-loads to the right of the point P and acting at

their centre of gravity, and let w_2 similarly replace the loads to the left of P; let also A C B be a curve so constructed that the ordinate y at any point, distant x from B, represents the amount of the bending moment at the point P due to a load equal to unity at that point; the moment at P due to the system of loads represented by w_1 and w_2 will be—

$$M = w_1 y_1 + w_2 y_2.$$

If the system now moves to the left a small distance dx, and it be assumed that no wheel-loads either pass P or come on to the beam, the bending moment at P becomes—

$$M + dm = w_1 (y_1 + dx \tan \beta) + w_2 (y_2 - dx \tan \alpha)$$
$$dm = w_1 \, dx \tan \beta - w_2 \, dx \tan \alpha$$
$$\frac{dm}{dx} = CP \left(\frac{w_1}{PB} - \frac{w_2}{PA}\right).$$

It is required that, for a maximum value of M, $\frac{dm}{dx}$ must change from positive to negative in passing through zero; it will be observed that the expression $\left(\frac{w_1}{PB} - \frac{w_2}{PA}\right)$ can only pass through zero by some of the loads passing the point P. The condition for a maximum moment at P is therefore that a load or wheel shall be at P, such that when a definite fraction of it is considered as belonging to the loads on one side of P, and the remainder as belonging to the loads on the other side of P, the expression $\frac{w_1}{PB} - \frac{w_2}{PA}$ shall be equal to zero,

or
$$\frac{w_1}{PB} = \frac{w_2}{PA},$$

or by adding the numerators and denominators—

$$\frac{w_1}{PB} = \frac{w_2}{PA} = \frac{w_1 + w_2}{PB + PA} = \frac{w_1 + w_2}{AB}$$

i.e.,
$$\frac{w_2}{p} = \frac{w_1 + w_2}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

that is to say, the average load per unit length on one side of the point in question must be equal to the average load per unit length on the whole beam.

The second condition resolves itself into finding that point P at which the bending moment shall be the greatest which can occur

in the beam, and also the corresponding position of the loads. Since the point of maximum moment in any beam under a given system of loads is also the point of zero shear, referring to Fig. 8, Plate 8, let w_1 and w_2 have their former values; let g represent the distance from B to the centre of gravity of the total load on the beam, and let P be the point of maximum moment; the condition for zero shear at P is—

$$R_A = \frac{(w_1 + w_2)\,g}{l} = w_2$$

or

$$\frac{w_1 + w_2}{l} = \frac{w_2}{g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Since the moment at P is to be the greatest which can occur in the beam, it must also be the greatest which can occur at P, and for a maximum moment at any point, by the preceding equation (1)

$$\frac{w_2}{p} = \frac{w_1 + w_2}{l},$$

hence, combining (1) and (2),

$$\frac{w_1 + w_2}{l} = \frac{w_2}{p} = \frac{w_2}{g}$$

whence $p = g$.

That is to say, the point of maximum moment in a beam will be as far from one end of the beam as the centre of gravity of all the loads is from the other end.

Referring again to Fig. 6, Plate 8, the supporting force at the right end of the beam is equal to 5·8 tons, and the maximum bending moment in the beam for all positions of the engine, which occurs under wheel 3, is equal to—

$$5 \cdot 8\,(6 \cdot 887) - 3 \cdot 325\,(3 \cdot 75) = 27 \cdot 47 \text{ (in tons and feet).}$$

The dead load on the stringer due to the weight of rails, guard-rails, transoms, etc., and the weight of the girder itself, is equal to 1·09 ton, which gives a maximum bending moment in the centre of 2·1, the total bending moment being therefore 29·57 (in tons and feet). In dimensioning the stringers, the most economical depth can be found from the formula—

$$D = 1 \cdot 27 \sqrt{\frac{m}{f\,t}},$$

which does not take into consideration the moment of resistance of the web.

D = economical depth.
m = bending moment in tons and inches.
f = safe working stress in tons per square inch.
t = thickness of web in inches.

The economical depth for the system of loads in use will be found to be 1 foot 6 inches.

Since the total bending moment was found to be 29·57 (in tons and feet), the cross-sectional area required in the flanges will be 5·8 square inches, allowing for a working stress of 4·8 tons per square inch in tension and compression, the consideration on which this working stress is adopted being discussed later.

In Fig. 9, Plate 8, the wheel-loads involved are shown in position for maximum shear in the stringers, which on investigation will be found to be 8·3 tons; that due to the dead load is 0·545 ton, giving a total of 8·85 tons; this makes the shearing stress in the web 1·7 ton per square inch, and the shear per foot 7·5 tons.

The shearing stress allowed in the web may be taken at—

$$\frac{12,000}{1 \frac{H^2}{3,000}} = 3 \cdot 6 \text{ tons per square inch,}$$

where H = the ratio of effective depth to thickness of web; a $\frac{3}{8}$-inch web is adopted, it being inadvisable to use a thinner plate for the purpose, while the rivets are $\frac{3}{4}$-inch in diameter and 3 inches pitch at the ends.

The loading for the cross girders is shown in Fig. 10, Plate 8, and on the foregoing considerations they are made 2 feet 9 inches in depth, with a $\frac{3}{8}$-inch web-plate, and are built with 10-foot flange-plates.

A close approximation to the actual weight of the main trusses may be found by the use of a method advocated by Professor Claxton Fidler, in his treatise on bridge-construction,[1] in which the system of using the following formula is explained:—

$$\text{Weight of two trusses} = w = \frac{L\,(p\,\Sigma\,\gamma\,\mu' + q\,\Sigma\,\gamma\,\mu'')}{1 - L\,\Sigma\,\gamma\,\mu}.$$

[1] "A Practical Treatise on Bridge-Construction," by T. Claxton Fidler, M. Inst. C.E., 2nd edition, p. 322.

The dead load for each panel-point may now be summed up :—

	Tons.
Calculated weight of two girders	=108·4
Steel-work in deck	= 23·8
Timber, etc. „	= 21·4
Wind-bracing (say)	= 8·0
	161·6

$$\text{or } \frac{161\cdot 6}{2 \times 16} = 5\cdot 05 \text{ tons per panel point.}$$

In computing the dead-load stresses in a truss, one-third of this panel-load is assumed to be taken on the top chord panel-point, and the remainder on the lower chord panel-point.

Figs. 11 and 12, Plate 8, illustrate the scheme of considering the trusses as being made up of two independent systems, for purposes of calculation. The loading is also shown, and the coefficient for each web-member is written along its length. The stresses in the chord-members are best obtained by taking moments about one of the panel-points.

Considering the panel IV–VI, the stress in post 4 will be :—

$$\begin{aligned} 1\cdot 5\,(W + w) + w &= 1\cdot 5\,(5\cdot 05) + 1\cdot 68 \\ &= 9\cdot 25 \text{ tons,} \end{aligned}$$

and that in the diagonal 4–VI will be :—

$$1\cdot 5\,(W + w) \sec \theta = 10\cdot 71 \text{ tons.}$$

Taking moments about the point VI, the stress in bar 4–6 is found to be :—

$$\begin{aligned} &20\cdot 2 \times 3 - 5\cdot 05 \times 3 - 2\cdot 52 \times 2\cdot 5 \\ &= 39\cdot 15 \text{ tons.} \end{aligned}$$

In dealing with the live-load stresses in a truss, certain assumptions are necessarily made as to the distribution of the load, and whereas in simple trusses it is possible by means of the method known as the "concentrated-load system," to compute the stresses in accordance with the exact conditions of loading, this method is not applicable in a case such as that under consideration. In this case the nearest approximation is obtained by using a system of panel concentrations, while the system of "engine excesses" serves as a valuable independent check. For the computation of the panel concentrations, such a position of the loads is selected as will give a maximum joint load at the first panel point, and this same position is retained for all the chord stresses. The load

diagram shown in Fig. 15, Plate 8, is that used, and calling the leading wheel No. 1 it will be found that the maximum load at point I is obtained when wheel No. 4 is at that point; any panel concentration for the given position of the loads may then be found from the equation—

$$P_n = \frac{M(n+1) - 2Mn + M(n-1)}{l},$$

where Mn, $M(n+1)$, and $M(n-1)$ are the summations of moments at the point in question, and those to the right and left of it respectively, of all the loads to the left of those points, and l is the panel length.

With wheel No. 4 at point I, the positions of the other wheels with respect to the panel-points will be the following:—

Wheel.	Point.	Distance of Wheel to Left of Point.
		Feet.
4	I	0·0
6	II	1·95
9	III	4·67
13	IV	0·545
15	V	2·57
End of uniform load and wheel 18	VI	5·235

and the computed values of M will be (in tons and feet)

M_0 . . . . = 0·0
M_1 . . . . = 49·28
M_2 . . . . = 253·54
M_3 . . . . = 594·81
M_4 . . . . =1,049·56
M_5 . . . . =1,657·37
M_6 . . . . =2,408·10
M_7 . . . . =3,277·66

The values of P may now be computed from the foregoing formula, and will be found to be

	Tons.
P_0	3·2
P_1	10·08
P_2	8·91
P_3	7·38
P_4	9·90
P_5	9·29
P_6	7·72
P_7	5·07

The panel concentrations can now be written on a skeleton diagram of the truss for convenience in arriving at the stresses: the loads for one of the component parts of the truss are shown in Fig. 13, Plate 8, and taking for illustration one of the bays, say No. (6–VIII), the reaction at the left end will be 31·258 tons.

With the centre of moments at point VIII the stress in bar 6–8 will be

$$4(31\cdot258)-\{7\cdot72+2(9\cdot90)+3(8\cdot91)+3\cdot5(5\cdot04)\}$$
$$=125\cdot03-71\cdot89$$
$$=53\cdot14 \text{ tons.}$$

For the stress in bar 6–VIII the position of the loads giving the maximum shear is shown in Fig. 14, Plate 8, the reaction at the left end will be found to be 10·92 tons, which, multiplied by 1·414, the secant of the angle of inclination of the bar, gives 15·44 tons as the stress in bar 6–VIII, the stress in post 6–VI, being equal to the shear, will be 10·92 tons. The stresses in the other bars may be found in a similar manner; the results are given in tabulated form in the Appendix.

The effect of wind-pressure must be provided for by a top and bottom lateral system of wind-bracing, taking each one-half of the pressure on the exposed surface, and also by a strong portal-bracing and transverse bracing from the vertical members; the top and bottom systems of bracing, with the main chords, become simply braced horizontal trusses, and the panel-loads are obtained on the assumption that when a train is not on the bridge the wind-pressure may reach 50 lbs. per square foot on twice the area of the elevation of one truss, but that when the bridge is covered by a train-load the wind-pressure cannot exceed 30 lbs. per square foot, and part of the lee girder will be protected; the wind-pressure on the train must be considered as a moving load affecting the lower wind-bracing. The following is a summary of the scheme of loading:—

	Upper Wind-Bracing.	At Lbs. per sq. foot.
Chords, ½	(Twice area of elevation of one truss)	30
Web, ½	(„ „ „ „ „)	50

	Lower Wind-Bracing.	
Chords, ½	Area of one truss Area of floor Moving train 10 square feet per foot	30
Web, ½	Area of one truss Area of floor Moving train 10 square feet per foot	30

These loadings are those for which sectional area must be provided in the chords and web members of the bracing, and it will be seen that when there is no train-load on the bridge the sectional area in the chords provided to take the stress due to the train-load is available for taking the stress due to wind-pressure. Compression in the lower chord will only take place when there is no train on the bridge, and to ascertain its amount the tension due to dead load must be compared with the compression due to wind-pressure at 50 lbs. per square foot. The wind-stresses are summarized in Figs. 16 and 17, Plate 8, and in the Appendix.

The following is the theoretical treatment of the portal-bracing, the object of which is to transmit the reactions of the top wind-bracing to the abutments; the batter-braces are considered as beams fixed at the lower end, the end cross-girder connections being made specially rigid in order to secure this result. Referring to Fig. 16, Plate 8, the position of the plane of contraflexure is given by,

$$X_0 = \frac{21 \cdot 37}{2} \frac{(21 \cdot 37 + 68 \cdot 74)}{(42 \cdot 74 + 34 \cdot 37)} = 12 \cdot 4 \text{ feet,}$$

and H and V by—

$$H = \frac{23 \cdot 1 + 1 \cdot 65}{2} = 12 \cdot 37 \text{ tons.}$$

$$V = \frac{24 \cdot 8 \times 21 \cdot 9}{15} = 36 \cdot 2 \quad ,,$$

The maximum bending moment in the batter-braces will then be $12 \cdot 37 \times 12 \cdot 4 = 153 \cdot 76$ (in tons and feet), and if their effective depth be taken as $1 \cdot 5$ foot the compressive stress is $\frac{153 \cdot 76}{1 \cdot 5}$ $= 102 \cdot 4$ tons; this stress may occur in either web of the batter-brace, and must be provided for in each; hence:—

	Tons.
Stress due to moment	$=102 \cdot 4$
,, ,, vertical reaction	$= 18 \cdot 1$
	$120 \cdot 5$

which multiplied by 2 gives $241 \cdot 00$ tons total stress for which area must be provided in each batter-brace.

The total stress in the diagonals will be $\frac{V}{8} \sec \theta = 6 \cdot 9$ tons,

while that in the top and bottom struts will be 31·58 and 20·8 tons, respectively.

In determining the unital stresses to be adopted, the practice will be followed of neglecting the hypothetical effect of fatigue, on the assumption that any diminution of the working strength which may ensue therefrom will be covered by making a sufficient allowance for impact or dynamic effect.

The following percentages of increase are allowed for rolling-over static-loads:

	Per Cent.
Sleepers	100
Stringers and cross girders	50
Truss members	25

The safe working stress for dead load of the steel to be employed may be assumed to be more than 7 tons per square inch, or allowing for secondary stresses, say 7 tons per square inch; then, adopting the formula "Constant $\left(1 + \frac{\text{min}}{\text{max}}\right)$" for determining the values for the different members, the unital stress may be arrived at in the following manner, taking for example the truss members:—

Mean ratio of dead load to live load = 1 : 1·29.
Ultimate working stress for dead load = 7 tons.

Ultimate working stress for live load—

$$= 7\left(\frac{1}{1 + \frac{25}{100}}\right) = \frac{4}{5} \times 7 = 5 \cdot 6 \text{ tons.}$$

Unital stress for dead- and live-load limit—

$$= \frac{(1 \cdot 29 \times 5 \cdot 6) + 1 \times 7}{2 \cdot 29}$$

$$= 6 \cdot 2 \text{ tons per square inch.}$$

Embodying this in the formula, "Constant $\left(1 + \frac{\text{min}}{\text{max}}\right)$"

$$\text{Constant}\left(1 + \frac{\text{min}}{\text{max}}\right) = 6 \cdot 2 \therefore \text{ Constant} = 4 \cdot 31.$$

The working stress for the compression members must be obtained from the formulas for columns, usually of the form—

$$\text{K}\left(1 + c\frac{l}{r}\right),$$

$\frac{l}{r}$ being the ratio of length to least radius of gyration.

The resistance of the steel rivets to shearing may be taken as four-fifths of the tensile strength of the material; and, in proportioning the rivet-area to plate-area in the connections, the ratio should not be less than 1·4 : 1.

The specification for the Burdekin Bridge required the steel used to be of mild and tough quality, manufactured in Great Britain by the Siemens-Martin process, and all the steel except for rivets to have an ultimate tensile strength when tested, both lengthwise and crosswise, of not less than 30 tons nor more than 34 tons per square inch of original section, with an elongation of not less than 18 per cent. measured on a length of 8 inches, while the steel used for bolts and rivets was required to have a tensile strength of not less than 28 tons per square inch with an elongation of not less than 25 per cent. measured on a length of 8 inches.

Proceeding to the construction of the bridge, the Burdekin River, like many others in Queensland, is, in the dry season, nothing but a small stream at the side of a wide bed of sandy gravel, but in the heavy tropical rains this stream quickly rises into a torrent about 40 feet deep. As the rains occur annually with some regularity, the flood-waters did not cause much inconvenience in founding the piers, but as the water-level in dry weather is only a few inches below the level of the sandy bed the use of a cofferdam was necessary to found all except one of the river-piers; a good rock foundation was obtained at a maximum depth of 15 feet below the surface, the rock consisting of coarse granite slightly decomposed on the surface; on this account it was necessary to clean out the foundation in the rock for about 2 feet, and in two of the piers, where the surface of the rock was in a rather worse condition, as much as 6 feet had to be taken out.

The piers were built of concrete from base to bed-stone, with blue basalt quoins in the cut-water, the lower portions, as far as the rock, being of concrete composed of 6 parts of broken stone (quartzite), 3 of river sand (screened), and 1 of Portland cement, while from the rock surface to the bed-stone the concrete was gauged 4, 2 and 1. A fair proportion of large stones, or plums, was used in the 6, 3 and 1 concrete, while the upper portions, of 4, 2 and 1 concrete, were built with three voids, 2 feet 6 inches square, which were filled with broken stone and sand, the voids being broken in the total height of the piers with three horizontal bond-walls 2 feet 6 inches thick; the outer surface of the concrete was floated over as a finish. The cofferdams were

of the simplest character, consisting of an inner and an outer casing of 9 inches by 3 inches soft-wood sheet-piling, grooved on both edges, the joint being made with a hard-wood strip; the sheet-piling, being in one length, was easily driven by hand through the loose sand, and followed exactly in outline the plan of the piers; the thickness of the clay wall was made 3 feet, and the inner timber wall was driven 2 feet outside the intended surface of the pier to allow of the timber framework and moulding-boards being tommed in from it. The inner timber walls were strutted from one to the other by two rows of struts wedged against horizontal stringers, the struts being knocked out as the concrete was brought up to the top of the cofferdam; the outer timber wall was strutted from the inner wall in a similar manner. Owing to the roughness of the rock surface a fair amount of water found its way under the clay wall, but not more than could easily be kept under by a 12-inch centrifugal pump.

The timber framing for carrying the piers up from ground-level consisted of six vertical studs with the feet bolted to the concrete already in position; the moulding boards were set to correct batter on the inside of these studs, and as the concrete was brought up, the temporary transverse bracing, which was necessary when the studs were fixed only at the toe, was knocked away and replaced by bolts into the concrete; these bolts were about 15 inches long with a nut on each end, and were afterwards unscrewed, the hole being filled up and floated over. The whole of the concrete was hoisted in barrows, and was not tipped from a greater height than 7 feet; a cask of cement was used to each gauge of concrete, the mixed sand and cement being shovelled on to a gauged quantity of previously wetted stone, and the whole turned over three times while the water was being added. It was considered a good day's work for a gang of eighteen men to place in position 30 cubic yards of concrete, which was about the maximum for each gang. The whole of the work was done by contract, at schedule rates, the cost to the Government for concrete, including floating, being 40*s*. 3*d*. per cubic yard for the 4, 2 and 1 concrete, and 35*s*. per cubic yard for the 6, 3 and 1 concrete.

The steelwork was all manufactured at the site, the imported rough material being trucked from Townsville, a distance of 70 miles. The workshops were situated on the eastern bank of the river, and the machine-tools were driven by a 21-HP. single engine, the drills available consisting of eight radial drills, six vertical drills and one multiple drill.

The first shipment of steel arrived on the ground in February,

1897, and the work of marking off the templates and drilling was commenced at once. The weight of steel to be drilled, shaped and part-riveted in the shop was 1,163 tons, the weight calculated from the detail quantities being 1,169 tons, which included the heavy end-attachments, and the continuous-girder approach-spans. The whole of the work was drilled, no punching being allowed, and the total number of holes to be drilled was estimated at 918,000. The average number of holes drilled per day of 10 hours for each radial machine was 250, at an average cost of 0·38*d.* per hole. A considerable amount of straightening was necessary for all bars and plates before drilling, and in the case of angle-bars for use in flanges most careful straightening was necessary, otherwise slight inequalities were left which squeezed out when the bars were riveted and necessitated re-chipping the ends to correct length. The riveting was done by machine as far as possible, the plant consisting of three pneumatic riveters; the length of the rivets ranged between 2⅛ inches and 5 inches, the rivets being all made in the shop by two men with one machine, at the rate of 2,000 to 2,500 per day, and at an average cost of 0·14*d.* per rivet. The total number of field rivets to be driven in each span was 15,657, and the average number per day was 150 machine-riveted, and 100 hand-riveted; of those driven by hand about 2½ per cent. were loose and had to be cut out and replaced, while the number spoilt by over-heating or burning was about 2 per cent.

In reference to the erection of the steel spans, those over the eastern and western bank of the river, which were clear of the main channel, and the third span, which was erected during the dry season, were built on a timber falsework, Fig. 2, Plate 8; while the remaining three spans were built on a steel trussed platform spanning the complete opening, which was moved in sections from span to span as each was completed, Figs. 2 and 3, Plate 8. This platform, which was known on the works as the "temporary truss," was constructed of four light steel pin-trusses, each of 250 feet span, with a central depth of 25 feet; they were of bowstring form, and were placed parallel to each other, 7 feet 6 inches apart from centre to centre of chords, the lower curved chords consisting of wrought-iron eye-bars, and the upper chord of angle-bars and plates, the trusses being braced transversely with ⅞-inch tie-rods. The method of using and transporting the trusses is clearly shown in Fig. 2, Plate 8. A central timber pier was constructed between the two concrete piers, and the temporary trusses were hoisted, one half at a time, the joint in the centre being made with bolts and nuts. As soon as the four trusses

were in position and jointed, and the transverse bracing secured, the work of erecting the permanent structure was commenced, while the temporary timber pier was withdrawn and moved to the next span. When the permanent work was sufficiently far advanced, the central joints of the temporary trusses were again broken and each half was lowered from the standing work on to two timber trestles placed in position to receive the ends; the trestles, with their load, were then moved transversely on to a tram line laid along the downstream side of the piers, by which means they were conveyed into position for hoisting in the next span. The weight of each temporary truss was 20 tons, and there were thus eight hoists of 10 tons each, or 5 tons on the tackle at each end. The work of disconnecting and lowering the four complete trusses, moving from one span to the next, hoisting, and remaking the joints, occupied under favourable conditions three weeks.

The permanent work was erected on the temporary trusses by means of a travelling gantry built of squared oregon, and the heaviest sections hoisted were the batter-braces weighing 3·28 tons each. The spans were built to a camber of 5 inches, the lower chords being accurately set to this camber with the level when first laid on the blocks, which had to be adjusted from time to time. In servicing the sections of the main trusses together, the lower chords were laid down first, accurately set to camber, and lined up; the posts and top chords were then hoisted into position, working from the centre towards the ends, and finally the main ties, wind-bracing and deck beams were erected in the order named; the greatest difference in length between bottom chords when riveted was $\frac{3}{16}$ inch in 246 feet.

To allow for the effect of the 5 inches of camber on the verticality of the posts, each bay of the top chord was made $\frac{9}{32}$ inch longer than the corresponding bay of the bottom chord, and to ensure an initial tension the tie-bars were cut $\frac{1}{8}$ inch to $\frac{1}{4}$ inch short, according to the sectional area of the bar, the holes in the gussets and bars being brought fair with plugs before riveting. The central tie-bars were, unavoidably, extremely long in proportion to their sectional area, and when the vibration due to wind would have been considerable, especially in the case of the counter-braces, a light bracing was introduced to stiffen them. The plates and bars were all put in in single lengths, some of the lower chord web-plates being as much as 39 feet long, while the bars averaged 43 feet 6 inches in length; some of these had to be specially rolled.

The verticals were of I-section with open web, except the hip

vertical, which was constructed of bars, while the chords were of the ordinary box-girder shape with open bracing on both the top and bottom sides. The whole of the steel-work received one coat of paint in the shop, the two final coats being put on after erection; the contract price for the finished work, including supply of material, manufacturing, painting and erection, was £28 5*s.* per ton.

The specification required each span when riveted in the shop to be tested with a dead load equivalent to 0·80 ton per lineal foot, and to be tested after erection with the rolling load for which they were designed, viz., the coupled engines, weighing 51·7 tons each, followed by a train-load of 0·66 ton per lineal foot to cover the entire span; it was, however, decided to allow the preliminary dead-load test to be made after the spans were finally riveted in position, and the first span on the eastern side of the river was tested in this way on 29 July 1898. Seven eight-wheeled wagons, loaded to an equal weight with steel rails, were run on to the span, the total load being 270 tons; the observed central deflection, taken with a suspended indicator and checked with a level, was $1\frac{3}{16}$ inch, with a negative set of $\frac{1}{50}$ inch immediately after the load was removed, the spans returning to the normal position after 12 hours.

The bridge was taken over from the contractor by the Government at the end of January, 1899, and when officially tested with the rolling load, the 250-foot spans gave an average central deflection of $1\frac{1}{4}$ inch, with a variation of not more than $\frac{1}{4}$ inch in the six spans.

The Paper is accompanied by an album of photographs, and by a series of drawings, from which Plate 8 and the Figures in the Appendix have been prepared.

[APPENDIX.

APPEN

TABLE OF STRESSES IN

Bay or Bar.		Dead and Live Load Stresses. Dead Load. Component Girder. No. 1.	No. 2.	Live Load. Component Girder. No. 1.	No. 2.	Total Stress.	Ratio. Min./Max.	Unital Stress.	Area Required.
		Tons.	Tons.	Tons.	Tons.	Tons.		Tons per Sq. In.	Square Inches.
0	1	22·58	19·76	34·94	27·79	105·07 / 42·84[1]	..	4·5	23·34 / 9·40[1]
1	2	18·94	23·99	28·74	32·25	103·93	..	5·5	18·90
2	3	31·57	,,	46·05	,,	133·86	..	,,	24·30
3	4	,,	34·10	,,	44·69	156·41	..	,,	28·44
4	5	39·15	,,	53·45	,,	171·39	..	,,	31·16
5	6	,,	39·14	,,	47·92	179·66	..	,,	32·66
6	7	41·68	,,	53·14	,,	181·88	..	,,	33·07
7	8	,,	39·14	,,	45·92	179·88	..	,,	32·72
0	I	10·10	8·84	15·63	12·43	47·00	0·40	6·03	7·79
I	II	,,	,,	,,	,,	,,	,,	,,	,,
II	III	18·94	,,	28·74	,,	68·95	,,	,,	11·43
III	IV	,,	23·99	,,	32·25	103·92	0·41	6·07	17·10
IV	V	31·57	,,	46·05	,,	133·86	,,	,,	22·05
V	VI	,,	34·10	,,	44·69	156·41	0·42	6·16	25·39
VI	VII	39·15	,,	53·45	,,	171·39	,,	,,	27·82
VII	VIII	,,	39·14	,,	47·92	179·66	0·43	6·16	29·16
2	II	14·30	..	20·77	..	35·07	..	3·20	10·96
3	III	..	11·78	..	17·83	29·61	..	,,	9·25
4	IV	9·25	..	15·53	..	24·78	..	2·90	8·54
5	V	..	6·73	..	12·91	19·64	..	,,	6·77
6	VI	4·21	..	10·92	..	15·13	..	2·70	5·60
7	VII	..	1·68	..	8·62	10·30	..	,,	3·80
8	VIII	1·68	..	7·03	..	8·71	..	,,	3·20
1	I	3·37		11·21		14·58	0·23	5·30	2·75
1	II	19·74	..	+ 0·85 −29·79	..	49·53	0·39	5·99	8·27
1	III	..	21·42	..	+ 0·44 −33·07	54·49	0·38	5·98	9·11
2	IV	17·86	..	+ 2·17 −29·36	..	47·22	0·33	5·73	8·24
3	V	..	14·28	..	+ 3·06 −25·20	39·48	0·28	5·52	7·16
4	VI	10·71	..	+ 5·30 −21·96	..	32·67	0·16	5·00	6·53
5	VII	..	7·14	..	+ 6·84 −18·25	25·39	0·28	5·52	4·60
6	VIII	3·57	..	+ 9·94 −15·44	..	19·01	0·18	5·00	3·80
7	IX	..	0·00	..	12·18	12·18	0·00	4·31	2·82
8	VI	0·00	..	9·94	..	9·94	,,	,,	2·30
7	V	..	,,	..	6·84	6·84	,,	,,	1·60

[1] Dead Load

DIX.

Members of Truss.

Wind Stresses. Wind Pressure. 30 lbs.	Wind Stresses. Wind Pressure. 50 lbs.	Wind Stresses. Unital Stress.	Wind Stresses. Area Required	Total Areas. Required.	Total Areas. Provided.	Sections. Plates or Angle-Bars.	Sections. Ins. Ins. In.	Sections. Plates.	Sections. In. In.
Lbs. per Sq. Foot.	Lbs. per Sq. Foot.	Tons per Sq. In.	Square Inches.	Square Inches.	Square Inches.				
..	241·0	6·0	40·10[1]	49·50[1]	54·20	4 4	12¼ × 7/16 3½ × 3½ × 7/16	1 2	25 × ½ 19½ × ½
13·50	..	"	2·25	21·15	30·98	4	do	2	do
24·60	..	"	4·10	28·40	"	4	do	2	do
33·80	..	"	5·63	34·07	37·98	4 4	do 4 × 7/16	2	do
41·00	..	"	6·83	37·99	"	4 4	3½ × 3½ × 7/16 4 × 7/16	2	do
46·10	..	"	7·68	40·34	42·35	4 4	3½ × 3½ × 7/16 6½ × 7/16	2	do
49·20	..	"	8·20	41·27	"	4 4	3½ × 3½ × 7/16 6½ × 7/16	2	do
50·20	..	"	8·36	41·08	"	4 4	3½ × 3½ × 7/16 6½ × 7/16	2	do
..	+ 24·3	"	..	7·79	20·83	4	3½ × 3½ × 7/16	2	18 × ⅜
− 26·60	+ 45·3	8·0	3·32	11·11	"	4	do	2	do
− 49·70	+ 63·2	"	6·21	17·64	"	4	do	2	do
− 69·20	+ 77·7	"	8·65	25·75	31·47	4	do	4	do
− 85·20	+ 89·10	"	10·65	32·70	32·78	4	do	4	do
− 97·60	+ 97·20	"	12·20	37·59	43·32	4 2	do 10 × ⅝	4	do
−106·50	+102·00	"	13·31	41·18	42·00	4 2	3½ × 3½ × 7/16 10 × ⅝	4	do
−111·80	+103·60	"	13·97	43·13	43·60	4 2	3½ × 3½ × 7/16 10 × ⅝	4	do
..	..	..	..	10·96	12·36	4	4½ × 3 × 7/16		
..	18·80	"	4·70	13·95	14·00	4	4½ × 3 × ½		
..	..	..	..	8·54	9·20	4	3½ × 3 × ⅜		
..	22·60	"	5·64	12·41	13·00	4	3½ × 3½ × ½		
..	..	..	..	5·60	8·44	4	3 × 3 × ⅜		
..	22·60	"	5·64	9·44	9·76	4	3 × 3 × 7/16		
..	..	..	..	3·20	8·44	4	3 × 3 × ⅜		
..	..	..	..	2·75	3·56	2 bars	6½ × ⅜		
..	..	..	..	8·27	8·26	2 do.	9¼ × ½		
..	..	..	..	9·11	9·26	2 do.	10¼ × ½		
..	..	..	..	8·24	8·26	2 do.	9¼ × ½		
..	..	..	..	7·16	7·26	2 do.	8¼ × ½		
..	..	..	..	6·53	6·53	2 do.	7½ × ½		
..	..	..	..	4·60	4·82	2 do.	6½ × 7/16		
..	..	..	..	3·80	3·84	2 do.	6 × ⅜		
..	..	..	..	2·82	3·09	2 do.	5 × ⅜		
..	..	..	..	2·30	3·09	2 do.	5 × ⅜		
..	..	..	..	1·60	2·34	2 do.	4 × ⅜		

only.

Figs. 18.

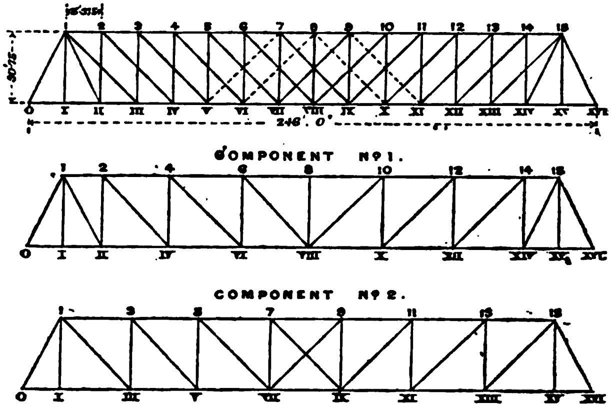


DIAGRAM OF TRUSS AND COMPONENTS.

Figs. 19.

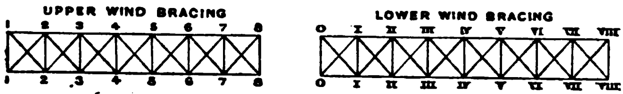


DIAGRAM OF WIND-BRACING.

TABLE OF STRESSES IN UPPER WIND-BRACING.

Bar.		Stress.	Unital Stress.	Area Required.	Make up of Section.	Area Provided.
1	2	30·70	8·0	3·84	1 angle-bar 4 inches × 4 inches × $\frac{5}{8}$ inch	4·07
2	2	18·10	3·1	5·84	2 „ 5 „ × 3½ „ × $\frac{3}{8}$ „	6·10
2	3	25·90	8·0	3·24	1 „ 4 „ × 3½ „ × $\frac{9}{16}$ „	3·41
3	3	4·28 14·80	3·1	6·15	2 „ 5 „ × 3½ „ × $\frac{3}{8}$ „	6·10
3	4	21·20	8·0	2·65	1 „ 3½ „ × 3 „ × ½ „	2·56
4	4	11·50	2·5	4·60	2 „ 3½ „ × 3 „ × $\frac{3}{8}$ „	4·60
4	5	16·50	8·0	2·06	1 „ 3 „ × 3 „ × $\frac{7}{16}$ „	2·06
5	5	4·28 8·20	2·5	4·99	2 „ 3½ „ × 3 „ × $\frac{7}{16}$ „	5·30
5	6	11·80	8·0	1·48	1 „ 3 „ × 2½ „ × $\frac{3}{8}$ „	1·64
6	6	4·90	2·5	1·96	2 „ 3 „ × 2½ „ × $\frac{3}{8}$ „	3·84
6	7	7·10	8·0	0·89	1 „ 3 „ × 2½ „ × $\frac{5}{16}$ „	1·38
7	7	4·28 1·61	2·5	2·36	2 „ 3 „ × 2½ „ × $\frac{3}{8}$ „	3·84
7	8	2·40	8·0	0·30	1 „ 3 „ × 2½ „ × $\frac{5}{16}$ „	1·38
8	8	1·65	2·5	0·66	2 „ 3 „ × 2½ „ × $\frac{5}{16}$ „	3·24

TABLE OF STRESSES IN LOWER WIND-BRACING.

Bar.		Stress.	Unital Stress.	Area Required.	Make up of Section.	Area Provided.
0	I	37·20	8·0	4·65	1 angle-bar 5 inches × 4 inches × $\frac{5}{8}$ inch	4·68
I	II	32·30	8·0	4·04	1 „ 4 „ × 4 „ × $\frac{5}{8}$ „	4·06
II	III	27·80	8·0	3·47	1 „ 4 „ × 3 „ × $\frac{5}{8}$ „	3·44
III	IV	23·30	8·0	2·91	1 „ 4 „ × $3\frac{1}{2}$ „ × $\frac{1}{2}$ „	3·06
IV	V	19·20	8·0	2·40	1 „ $3\frac{1}{2}$ „ × $3\frac{1}{2}$ „ × $\frac{7}{16}$ „	2·49
V	VI	15·10	8·0	1·88	1 „ $3\frac{1}{2}$ „ × 3 „ × $\frac{3}{8}$ „	2·01
VI	VII	11·30	8·0	1·41	1 „ 3 „ × 3 „ × $\frac{5}{16}$ „	1·54
VII	VIII	7·60	8·0	0·95	1 „ 3 „ × $2\frac{1}{2}$ „ × $\frac{5}{16}$ „	1·38

(*Paper No. 3196.*)

"Experimental Investigations on the Action of Sea Water in accelerating the Deposit of River Silt and the Formation of Deltas."

By Leveson Francis Vernon-Harcourt, M.A., M. Inst. C.E.

The formation of deltas by sediment-bearing rivers, especially when discharging into tideless seas, has been attributed to two causes, namely: (1) the checking and eventual stoppage of the issuing current on encountering the vast inert mass of sea water in front of the mouth of the river, causing the rapid arrest of the heavier materials rolled along the river-bed, and the gradual settlement of the silt carried in suspension by the river; and (2) the acceleration of the deposit of the suspended silt by the action of the sea water upon it. The first cause is a well-understood physical action, which increases with the amount of retardation of the river-current on emerging into the open sea, and with the density of the matter in suspension. The second cause partakes somewhat of the nature of a chemical action, depending upon whatever greater influence may be possessed by sea water in promoting the settlement of the suspended silt, than the river water in which the silt has been brought down in suspension, resulting from differences in chemical composition.

This acceleration of deposit by sea water appears to have been accepted by geologists as the main cause of the formation of deltas, though the subject has been very little investigated, being based upon some experiments made on the rates of deposit of Mississippi silt in river water, sea water, and some saline solutions, by Mr. Sidell, one of the engineers engaged in the early surveys of the mouths of the Mississippi river, and recorded by him in a report dated 25 January, 1839, published in Humphreys and Abbot's book on the Mississippi.[1] No details are given of these experiments; but the solutions employed were made with common salt, Epsom salt, alum, sea water, brine from salt springs, and sulphuric acid; and it is stated that "the river water alone took from

[1] "Report upon the Physics and Hydraulics of the Mississippi River," Capt. A. A. Humphreys and Lieut. H. L. Abbot. Enlarged Edition, 1876, Appendix A, No. 2, p. 500.

10 days to 14 days to settle, while the solutions became perfectly limpid in from 14 hours to 18 hours, or from one-fifteenth to one-eighteenth part of the time." From these results, Mr. Sidell concludes "that the earthy matter is deposited more suddenly than would be the case if it depended on the check of velocity alone; that the bars will be formed just at the débouchés, or where the salt water is first met; and that the greater the quantity of water brought down, the sooner, on account of the sudden precipitation, will the bars be formed at the débouchés."

Experiments on Rates of Deposit of River Silt.—The results of Mr. Sidell's experiments were brought to the Author's notice in 1894, by some correspondence on his Paper on "The Training of Rivers," contributed by Mr. J. V. Wilfrid Amor;[1] and the results appeared sufficiently remarkable, and the subject of the influence of sea water on the deposit of silt of adequate interest, in regard to the formation of deltas, to merit further investigation. Accordingly, samples were obtained by the Author, in 1894–95, of the silty sediments of the Rhone, the Danube, the Dnieper, the Nile, the Hugli, and the Mississippi.[2] The silt from the Dnieper was sent in place of silt from the Volga which had been asked for by the Author; but though the Dnieper is not a deltaic river, the sample of its silt possesses the interest of differing materially in composition and rate of deposit from the samples of silt from the other rivers.

Cylindrical glass tubes, 4 feet long, and between $\frac{15}{16}$ inch and 1 inch in diameter, were employed for the experiments. In order to render the conditions of the experiments as uniform as practicable, the silt from each river was passed through a fine sieve having about 7,400 meshes to the square inch, and an ounce of this sifted silt was used in each experiment. After closing the bottom of the tube with a cork, the ounce of silt was put in; and the tube was then filled with the liquid to be experimented with, to a height of 3 feet. The tube was next closed by a cork at the top, and after thoroughly shaking up the silt in the liquid the tube was set in a vertical position and the settlement of the silt was observed.

The first experiments showed that there was little difference between the rate of deposit of the silt in sea water and in the fresh water supplied by the waterworks from the Thames, but that the settlement took place much more slowly in distilled water; and consequently distilled water was adopted as the standard

[1] Minutes of Proceedings Inst. C.E., vol. cxviii. p. 107.

[2] These samples were kindly supplied to the Author by Mr. A. Guérard, Mr. C. H. L. Kühl, Mr. V. de Timonoff, Mr. W. Willcocks, Mr. P. W. Soutter, and Mr. C. Donovan.

fresh water. This result seemed to indicate that some river waters might, on account of the salts contained in solution in them, be as efficient in promoting the deposit of silt as sea water is. With the exception of the Nile silt, there was no sign of that great difference in the rate of settlement of the samples of silt as a whole in sea water and in fresh water, recorded by Mr. Sidell, unless mere turbidity is taken into account.

A saturated solution of Tidman's sea salt, having a specific gravity of 1·200, produced a notable acceleration in the deposit of all the samples of silt, as compared with their rate of settlement in sea water with a specific gravity of 1·024. This acceleration, however, in the saturated solution, in comparison with sea water, was not at all commensurate with the increased strength of the solution, and must be affected by the considerable augmentation in the specific gravity of the liquid. The degree of saltness, therefore, of the sea into which a river flows must affect the influence of its waters on the silt discharged into it, though not in proportion to the amount of salts in solution; and the waters of the Dead Sea should therefore prove more effective in promoting the deposit of silt than ordinary sea water, in spite of their greater specific gravity.

In carrying out, with the help of his assistant, Mr. Edward Blundell, experiments on the deposit of silt, as opportunity permitted between 1896 and 1899, the Author, besides observing the relative rates of settlement of the samples of river silt in sea water, Thames water, and distilled water, has endeavoured to gain an insight into some of the other problems relating to the subject. Thus it appeared of interest to try to ascertain whether differences in the composition of the silt could explain to some extent the differences in rate of deposit exhibited by the different samples of silt in the same solution; also which salts, constituting the main ingredients in solution in sea and river water, have the chief influence in accelerating the deposit of silt; and, lastly, how far samples of the chief substances shown by analysis to enter into the composition of the samples of river silt, taken separately manifest differences in their rates of deposit in the various solutions experimented upon, which might possibly indicate their relative influence on the deposit of the samples of silt.

Composition of Samples of River Silt.—Analyses of the six samples of river silt were made by Dr. A. Voelcker for the Author, the results of which are given in Table I. These analyses show that more than eleven-twelfths of the Dnieper silt consists of sand, and that there is a large proportion of sand in the silt of the Mississippi, the Danube, and the Hugli, whilst the smaller proportion of sand in the Rhone silt is compensated for by

TABLE I.—ANALYSES OF RIVER SILT.

Substances.	Hugli.	Rhone.	Danube.	Dnieper.	Nile.	Mississippi.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Organic matter and combined water	3·21	1·73	3·58	1·24	5·91	4·16
Oxide of iron and alumina . . .	13·78	6·92	10·08	3·02	21·25	9·55
Lime	3·64	19·24	4·56	1·41	2·40	1·16
Carbonic acid . .	4·41	14·91	5·66	1·90	7·78	2·69
Magnesia and alkalies	0·28	4·80	0·21	0·21		0·66
Silica and insoluble silicates . . .	74·68	52·40	75·91	92·22	62·66	81·78
Totals . . .	100·00	100·00	100·00	100·00	100·00	100·00

a large quantity of carbonate of lime and magnesia, constituting with the sand nearly four-fifths of the whole. Irrespective of the sand, which in every instance amounts to more than half of the total materials, clay predominates considerably over the rest of the ingredients in the Nile silt, and to a minor extent in the Hugli silt; whilst in the silts from the Danube and the Mississippi, the clay amounts to about half the remaining constituents after eliminating the sand. The Nile and Mississippi samples contain the largest quantity of organic matter, and the Danube and Hugli samples come next in this respect; but the proportion of this constituent is small, not reaching even in the Nile silt quite one-seventeenth of the whole, and only amounting to about one-thirtieth in the Danube and Hugli silts.

The analyses merely represent the composition of the special samples of silt sent to the Author, collected in each case at some particular time and place; whilst the silt in each river must vary in constitution according to the locality, the time of year, the stage of the river and the relative discharge of its tributaries. It is, however, important to note, in relation to the experiments, that the sample of Nile silt was obtained by collecting the mud deposited from bottles filled daily with Nile water, at a distance from the shore, during a period of 41 days in September and October, 1894; whereas the Author understands that the other samples of silt were taken from the deposit which had taken place in the bed of the respective rivers. From the slow rate of settlement of Mississippi silt, even in sea water and other saline solutions, recorded by Mr. Sidell, it is evident that his experiments dealt with the very finest silt in suspension in the Mississippi, and that the period of settlement given was continued till the solution became perfectly clear. Accordingly, the Nile mud, col-

T 2

lected from the top layer of the river, doubtless corresponds in fineness and lightness to the silt experimented upon by Mr. Sidell far more closely than the other samples of silt; and it is the only sample of silt the settlement of which in distilled water at all approximately accorded with the slow rate in river water given by Mr. Sidell. The silt, however, carried down by a river, and eventually discharged into the sea, is not fairly represented by merely the fine light matter carried in suspension in the upper layers of the river water, for it has been ascertained that the silt brought down by a river in flood increases in volume and density with the depth below the surface; and the heaviest particles are carried along in successive stages, being rolled along the bed or scoured from sandbanks by a rising flood, and brought to rest or dropped as the flood subsides, remaining undisturbed till the next flood puts them in motion again and carries them down another stage.

Principal Substances in Solution in Sea Water and River Water.—Sodium chloride, known as common salt, constitutes about 78 per cent. by weight of the salts in solution in sea water; and the only other salts entering appreciably into its composition are magnesium chloride constituting about 9½ per cent. of the soluble salts, magnesium sulphate 6 per cent., calcium sulphate nearly 4 per cent., and potassium chloride, or in some analyses potassium sulphate, to the extent of only 2½ per cent. of the soluble salts.[1] The whole of the soluble salts of sea water constitute about one-thirtieth part of its weight.

Taking the weights of the salts in solution in sea water in grains per gallon, in order to compare them readily with the analyses of substances in solution in river water, which are generally given in this form, they are, for the analysis selected, sodium chloride 1,851 grains, magnesium chloride 221 grains, magnesium sulphate 145 grains, calcium sulphate 93 grains, potassium chloride 52 grains, and calcium carbonate only 3⅓ grains.

River water contains a much smaller quantity of salts in solution than sea water, even without taking the sodium chloride in the latter into account; and its composition varies with every stage of the river, and depends upon the strata through which the river flows, and the extent to which it is fed by underground springs which have collected salts in their course. From some analyses of the waters of rivers which serve to supply large towns in England and Scotland, a gallon of Thames water was found to contain 10⅝ grains of calcium carbonate, 1¼ grain of magnesium

[1] "Treatise on Chemistry," Professors Roscoe and Schorlemmer, vol. i. p. 257.

carbonate, and 3 grains of calcium sulphate. In the Trent, the amounts of these salts were ½ grain, 5⅜ grains, and 21½ grains per gallon respectively; in the Don, 2¼ grains, 1 grain, and ⅛ grain, whilst in the Dee, the total amount of these three salts was only 1⅓ grain per gallon.[1] From an analysis of the waters of the Rhone at the confluence of the River Cèze, the calcium salts in solution were found to amount to about 8½ grains per gallon; and an analysis of the waters of the Danube at Daggendorf gave a very similar quantity of calcium salts. The results of several analyses show that the waters of the Hugli, at various points above Calcutta, contain 7 grains to 11 grains of calcium carbonate per gallon, and about 4 grains of magnesium carbonate on the average, but no calcium sulphate; whilst small variable quantities of sodium carbonate have been found, not exceeding 1½ grain per gallon.[2] In the Nile also, there are about 7 grains to 9 grains of calcium carbonate per gallon, and small quantities of salts of magnesium, sodium, and potassium, varying in amount with the stage of the river.[3] A sample of water taken from the Mississippi at New Orleans at the end of 1898, when the river had begun to rise, was found to contain 4 grains of calcium carbonate per gallon, 1 grain of magnesium carbonate, 1½ grain of sodium carbonate, and 8½ grains of sodium chloride per gallon, being about half the amount given in an analysis of water from the Trent. The amount of sodium chloride in a tidal river necessarily varies according to the locality, the stage of the river, and the state of the tide, even at a considerable distance from the mouth of the river, as is well illustrated by analyses of the water of the Hugli at high water during the dry season, which give the amount of sodium chloride in a gallon of water in March as 6 grains at Cossipur, about 100 miles up the river, 0·6 grain at Pultah, about 11 miles higher up, and 0·7 grain at Chinsurah, about 8 miles further up; whilst in May, when the flood-tide is strongest, the amounts were 32½ grains at Cossipur, 3·6 grains at Pultah, and 1·6 grain at Chinsurah. The organic matter in solution in the rivers mentioned, according to the analyses referred to, ranges from a maximum of 7 grains per gallon in the Hugli just above Calcutta, 3⅔ grains in the Trent, and about 3 grains in the Don, Danube, and Nile, down to 1⅜ grain in the Dee, and a very small amount in the Mississippi at New Orleans.

The principal substances, accordingly, which are found in solution in river waters are calcium carbonate, calcium sulphate, magnesium

[1] "Treatise on Chemistry," Professors Roscoe and Schorlemmer, vol. i. p. 255.

[2] "Report on the Water of the Hooghly," F. M. Macnamara. Calcutta, 1863.

[3] Minutes of Proceedings Inst. C.E., vol. lx. p. 376.

carbonate, a small amount occasionally of sodium carbonate, a very variable quantity of sodium chloride, and organic matter.

Results of Experiments on Rates of Deposit.—The samples of silt from the Hugli, the Rhone, and the Danube, were alone sufficient

TABLE II.—TIME OF SETTLEMENT OF DELTAIC SILTS AND COMPONENT SUBSTANCES IN VARIOUS SOLUTIONS, IN MINUTES PER FOOT.

Solution.	Strength of Solution.	Deltaic Silts.			Component Substances.		
		Hugli.	Rhone.	Danube.	Calcium Carbonate.	Peat.	China Clay.
		Minutes.	Minutes.	Minutes.	Minutes.	Minutes.	Minutes.
Sea salt, saturated (Specific gravity, 1·200) . . .	..	7½	7	6⅔	13	..	24
Sea water (Specific gravity, 1·024 and 1·018) . . .	$\frac{1}{30}$	23	24	26	12	35	93
Thames water . .	$\frac{1}{3,500}$	27	25	34	18	25	71
Pond water	..	22	14	30	11	20	21
Distilled water . .	..	56	32	65	14	54	65
Sodium chloride (Specific gravity, 1·058) . . .	$\frac{1}{10}$	23	29	28	17	21	151
Magnesium chloride (Specific gravity, 1·030) . . .	$\frac{1}{10}$	28	34	31	30	22	135
Magnesium sulphate (Specific gravity, 1·040) . . .	$\frac{1}{10}$	37	40	38	14	34	165
Calcium sulphate .	$\frac{1}{420}$	23	22	26	9	24	125
Potassium chloride (Specific gravity, 1·052) . . .	$\frac{1}{10}$	16	17	20	15	28	156
Potassium sulphate (Specific gravity, 1·050) . . .	$\frac{1}{11 \cdot 8}$	17	21	25	11	24	152
Calcium bicarbonate	$\frac{1}{2,700}$	26	27	31	12	35	84
Magnesium carbonate (Specific gravity, 1·018) .	$\frac{1}{48}$	30	38	40	9	35	67
Sodium carbonate (Specific gravity, 1·032) . . .	$\frac{1}{10}$	30	45	51	10	..	180

in quantity to be subjected to experiments on deposit in solutions of the chief substances contained in sea water and river water, as well as in sea water and distilled water. Experiments were also made in the same solutions with china clay, as representing pure

clay of uniform composition, calcium carbonate, as being the salt of lime found in river silt, and peat, which was used as the most uniform substance available constituting vegetable organic matter. The solutions were made by dissolving each very soluble salt in ten times its weight of distilled water; and in the case of the sparingly soluble salts, concentrated solutions were used. For a solution of organic matter, water from a pond was employed, to which only rain-water, vegetable matter, and aquatic insect life have access. The results obtained are given in Table II.

Since the rate of settlement became slower as the material got more concentrated in the lower part of the tube, especially with such bulky substances as china clay and peat, the rate has been given for the first foot from the top, except in the case of the peat, where, owing to the floating of a small quantity in every instance, it became necessary to measure the period of settlement for the foot between 6 inches and 18 inches from the top of the solution.

The few experiments possible on the rate of settlement of the limited quantities of silt received from the Dnieper, the Nile, and the Mississippi, gave the following results:—

TABLE III.—TIME OF SETTLEMENT OF RIVER SILTS IN VARIOUS SOLUTIONS, IN MINUTES PER FOOT.

Solution.	Dnieper.	Nile.	Mississippi.
	Minutes.	Minutes.	Minutes.
Sea Salt, saturated	4	10	9
Sea Water	12	18	30
Thames Water	13	20	36
Distilled Water	20	3 days.[1]	57

Experiments were also made with silver sand pounded very fine; but as this sand always settled down to the bottom of the solution in two or three minutes, it appeared unnecessary to continue these experiments.

The figures in Table II show that, whilst the deposit of silt is much more rapid in a saturated solution of sea-salt than in any other solution, the rate of settlement in sea water differs little from that in a stronger solution of its chief ingredient, sodium chloride, as well as in a solution of another constituent, namely, calcium sulphate. The rate of deposit of silt in Thames water also closely approximates to the rate in a solution of its principal

[1] The silt settled in this period to the bottom of the tube, but the water remained somewhat turbid above.

salt, calcium carbonate. The solutions in which the silts deposit most quickly, next to a saturated solution of sea salt, are the solutions of potassium chloride and potassium sulphate, and pond water, followed pretty closely in this respect by the solution of calcium sulphate, sea water, the sodium chloride and calcium bi-carbonate solutions, and Thames water. The deposit of silt was slowest in distilled water; and, unlike solutions of salts, the distilled water remained more or less cloudy above for a long time after the deposit of the silt had been practically completed. The Rhone silt settled in distilled water more quickly than the silts from the Hugli and the Danube, in spite of its smaller proportion of sand, evidently on account of the large quantity of calcium carbonate it contains, and the small amounts of clay and organic matter in its composition (Table I).

Out of the six samples of silt, the Dnieper silt naturally settled quickest in all the experiments, owing to the large amount of sand and the small quantities of clay and organic matter it contained; and, with the exception of the Hugli silt, the samples of silt settled in distilled water in the order in which they would stand in regard to the amount of sand and calcium carbonate in their composition. Though the Hugli silt settled rather more quickly in distilled water than the Danube silt, in spite of its containing more clay in its composition, its final clearing was slower. The very slow settlement of the finer particles of the Nile silt may be traced to the large proportion of clay and organic matter in its composition, and to the manner in which the sample was obtained from the silt carried in suspension in the upper layers of the river water.

With the exception of sand, which always settles rapidly, the substances selected as the best available representations in a pure state of the principal constituents of silt, fail to exhibit as a whole much accordance in settling with the rates of deposit of the river silts, except in a saturated solution of sea salt, pond water, Thames water, calcium bi-carbonate solution, and sea water; but this may be attributed to the rate of settlement of china clay being apparently much more retarded by an increase in the specific gravity of the solution than the samples of silt, except in a saturated solution of sea salt and a magnesium carbonate solution.

Influence of Strength of Solution on Rate of Settlement.—On comparing the strengths of the different solutions experimented upon, as given in Table II, with the rates of settlement of the silts in them, it became evident that the rate of settlement of silt cannot always increase with the strength of the solution, except apparently in the case of the solution of Tidman's sea salt. For

instance, the settlement of silt in sea water, containing salts in solution equivalent to one-thirtieth of its weight is slightly quicker than in a 10 per cent. solution of sodium chloride, and very nearly the same as in a 1 in 420 solution of calcium sulphate; whilst its rate of settlement in Thames water, containing in solution salts of only $\frac{1}{3500}$ part of its weight, approximates closely to its rate in a 1 in 2,700 solution of calcium bi-carbonate. To test definitely the correctness of the conclusion deduced from the various experiments, that an increase in the strength of a solution of the salts experimented on does not necessarily increase the rate of deposit of silt, observations were made of the rates of deposit of the Hugli, Rhone, and Danube silts, in a 1 in 60 solution of sodium chloride, which, compared with their settlement in a 10 per cent. solution, gave 20¾ minutes per foot in place of 23 minutes for the Hugli silt, 24½ minutes instead of 29 minutes for the Rhone silt, and 23¼ minutes instead of 28 minutes for the Danube silt, showing that the samples of silt settle quicker in a 1 in 60 solution than in a 1 in 10 solution of sodium chloride, and proving that the maximum rate of deposit does not always correspond with the maximum strength of the solution. It is evident, however, that there must be some limiting diluteness of the solutions, beyond which the rate of settlement of the silt must decrease; and this limit must depend upon the nature of the solution, the constitution of the silt, and the relation of the volume of the solution to the volume of the silt.

The apparent conflict between the results of this last experiment and the acceleration of the settlement of silt by concentrating the solution of sea salt, seems capable of explanation by the following considerations. Two of the salts which in solution have been shown by experiment to have a greater influence on the rate of deposit than sodium chloride, namely, potassium chloride and calcium bi-carbonate, are present in such very small quantities in ordinary sea water, that they are too diluted to exert their greatest influence on the settlement of silt; and the concentration, accordingly, of the solution of sea salt increases their proportion in the solution, and consequently their influence on settlement, without materially modifying that of the salts present in larger quantities.

Experiments on Settlement of Silt in Weak Solutions.—In view of the quicker rate of deposit of silt in a 1 in 60 solution of sodium chloride than in a 1 in 10 solution, the Author has endeavoured to ascertain approximately the strengths of the solutions of some of the principal salts contained in sea and river waters, which cause the most rapid deposit of silt. With sodium chloride, a 1 in

125 solution gave the quickest rate of settlement, reaching 19 minutes per foot for the Hugli silt, 24¼ minutes per foot for the Rhone silt, and 23 minutes per foot for the Danube silt, only slightly quicker than with a 1 in 60 solution, but a little more so than with a 1 in 200 solution.

With magnesium chloride, the settlement of silt was on the whole quickest with a 1 in 200 solution, in which the rate was 19½ minutes per foot for the Hugli silt, 20½ minutes for the Rhone silt, and 19 minutes for the Danube silt, though there was little appreciable difference in the rate between that in a 1 in 300 solution and that in a 1 in 100 solution; but a 1 in 75 solution gave a distinct slackening in the rate of deposit, with 20½ minutes, 23¾ minutes, and 21¾ minutes per foot respectively.

With magnesium sulphate, which with a 10 per cent. solution gave a slower rate of deposit than the other solutions of salts, with the sole exception of sodium carbonate, which is rarely found in river water, the rate of settlement of silt was quickest with a 1 in 500 solution, in which the rates were 16½ minutes per foot for the Hugli silt, 19¾ minutes per foot for the Rhone silt, and 17½ minutes per foot for the Danube silt.

Potassium chloride causes the quickest settlement of silt, with a 10 per cent. solution, of all the salts experimented with, as shown by Table II; but it furnishes still quicker results with weaker solutions, the quickest rate being attained with about a 1 in 60 solution, in which the Hugli silt settled 1 foot in 10½ minutes, the Rhone silt in 15 minutes, and the Danube silt in 13 minutes.

Calcium sulphate, which, next to calcium bi-carbonate in the presence of free carbonic acid gas, is the most sparingly soluble of the salts used, might have been expected to give the quickest settlement of silt in a saturated solution of only 1 in 420, especially as the settlement of the silt in this solution was quite as quick as in sea water; but experiment proved that still weaker solutions caused a more rapid settlement of silt. Thus the settlement of silt was quicker in a 1 in 1,500 solution than in a 1 in 420 solution, but somewhat quicker still in a 1 in 1,000 solution, averaging 16½ minutes per foot for the Hugli silt, 18 minutes for the Rhone silt, and 19 minutes for the Danube silt. These results furnish an explanation of the cause of silt settling in Thames water, with its small quantities of salts in solution, only a little more slowly than in sea water with its much larger proportion of salts in solution; for the chief salts in solution in Thames water are calcium bi-carbonate and calcium sulphate, very weak solutions of which have more influence in promoting the deposit of silt

than the stronger solutions of the other salts experimented with, except potassium chloride. Moreover, the considerably quicker rate of deposit of silt in a much stronger solution of potassium chloride than is contained in sea water accounts for the very rapid settlement of silt in a concentrated solution of sea salt, notwithstanding the high specific gravity of the liquid.

Experiments have also been made on the rate of settlement of calcium carbonate and china clay (which next to sand constitute the principal ingredients of river silt) in solutions of the salts of such strength, as mentioned above, which occasioned the quickest rates of settlement, to ascertain how far these substances, like silt, settle more quickly in these weak solutions than in the strong solutions originally employed. Comparing the results given in Table II with the following Table, in which the rates of settlement of the silts in the most efficient solutions are collected together, and also of calcium carbonate and china clay in similar solutions, the influence of the strength of the solutions on the rates of settlement is clearly indicated.

In Table IV, china clay again exhibits, as it did in Table II, a want of accordance in its settlement with the relative rates of deposit of the silts in the different solutions, indicating that china clay cannot be regarded as fairly representing in its behaviour the clay contained in river silts, either on account of the solutions of salts not acting in the same manner on china clay as on the clay of river silt, or owing to the fineness, lightness, or the cohesion of the particles of china clay when not separated by the intermixture of sand and carbonate of lime with them. The more rapid rate, however, of the settlement of carbonate of lime and china clay in these weaker solutions of salts than in the 10 per cent. solutions, as exhibited by a comparison of Table IV with Table II, conforms in a general way with the settlement of the silts in the respective solutions.

Conditions affecting the Settlement of River Silt.—Although sodium chloride has an accelerating influence on the deposit of river silt, the other principal salts in solution in sea water, namely magnesium chloride, magnesium sulphate, potassium chloride, and particularly calcium sulphate, have a considerably greater influence in promoting the deposit of silt in proportion to the amounts of these salts contained in sea water. Moreover, the proportions in which magnesium chloride, magnesium sulphate, and calcium sulphate are present in sea water, do not greatly differ from those for which the rate of settlement of silt has been found by experiment to be a maximum in simple solutions of these salts. Accord-

TABLE IV.—TIME OF SETTLEMENT OF DELTAIC SILTS, CALCIUM CARBONATE, AND CHINA CLAY, IN SOLUTIONS OF SALTS OF DEFINITE STRENGTHS, IN MINUTES PER FOOT.

Solution.	Strength of Solution.	Deltaic Silts.			Substances.	
		Hugli.	Rhone.	Danube.	Calcium Carbonate.	China Clay.
		Minutes.	Minutes.	Minutes.	Minutes.	Minutes.
Sodium chloride	$\frac{1}{60}$	20¾	24½	23¼	10	79
„ „	$\frac{1}{125}$	19	24¼	23	9¼	98
Magnesium chloride . . .	$\frac{1}{200}$	19½	20½	19	13¾	90
„ sulphate . . .	$\frac{1}{500}$	16½	19¾	17½	7½	69
Calcium sulphate	$\frac{1}{1,000}$	16½	18	19	7	71
Potassium chloride . . .	$\frac{1}{60}$	10½	15	13	8¾	111

ingly, though it might be difficult to determine the relative influences of the various salts in solution in sea water in accelerating the deposit of silt, it is evident that their several effects in promoting deposit are not cumulative, otherwise the settlement of silt in sea water would be much more rapid; and it appears probable from the experiments that the slower rate of settlement of silt in sea water than in solutions of magnesium chloride, magnesium sulphate, and calcium sulphate, of strengths corresponding to the proportions of these salts in sea water, must be attributed either to the large amount of sodium chloride in sea water giving it the preponderating influence and neutralizing the action of the other salts which are more efficient than sea water when alone in solution, or to the influence of one or more of the specially active salts being retarded by the increased specific gravity due mainly to the sodium chloride in solution, or by some interference with the normal action of the several salts in solution in consequence of the presence of other salts.

If river water were perfectly pure, sea water would have a marked effect in causing the deposit of the lighter portions of silt brought down in suspension by the river, as soon as the turbid waters discharged into the sea become intimately mixed with the sea water; but these conditions are in reality never fully realized. In the first place, river water invariably contains some calcium

bi-carbonate, calcium sulphate, or organic matter in solution, small quantities of which substances promote the deposit of silt as effectually as sea water does; and therefore river water approximates to sea water in its influence on the deposit of silt, according to the amount of these substances contained in solution in it. River water may, indeed, be as efficient in causing silt to settle as sea water is; and in such a case, the settlement of the silt carried in suspension by the river cannot be affected by admixture with sea water, but must be wholly due to the arrest of the current on entering the sea. Secondly, it must be borne in mind that river silt consists of a mixture of sand, calcium carbonate, clay, and organic matter. Sand is practically unaffected by the nature of the water in which it is suspended, and settles directly the river current is arrested; whilst the settlement of calcium carbonate is only slightly modified by the composition of the fluid in which it floats. Organic matter also appears to have its rate of deposit altered only within very moderate limits by variations in the constitution of the water in which it is immersed; and it is in fact almost wholly the finer particles of clay in suspension, mingled possibly with a little organic matter, which, as indicated by the experiments with Nile silt, if borne along by fairly pure river water, are deposited by admixture with sea water. Lastly, however, it must be noted that this very fine silt floating in the upper layers of the river water, does not really mix at once with the sea water on being discharged from the mouth of the river, but is at any rate partially borne along by the issuing fresh-water current, over the top of the denser sea water, to a considerable distance from the shore, varying according to the velocity and volume of the river water flowing into the sea. Thus the turbid water issuing from the Rhone was seen by the Author, in 1892, about 6 miles seawards from its mouth, and occasionally in flood time it extends to double that distance; the muddy outflow from the Nile is very distinctly visible crossing the outlet of Port Said Harbour, at a distance of about 35 miles from the nearest mouth of the river; and the silt-bearing current issuing from the Amazon is said to have been observed at sea 300 miles beyond its mouth. Moreover, the finest silt is very readily kept in suspension by the slightest motion of the water resulting from currents, winds, or waves; and if the action of sea water on river silt was as rapid as assumed by Mr. Sidell, a turbid river like the Hugli should become clear on entering the Bay of Bengal, whereas its waters are as densely charged with reddish-brown silt beyond its outlet, as at Calcutta, 100 miles up the river.

Conclusions as to the Influence of Sea Water on the Formation of Deltas.—The fine, light, clayey matter which renders the upper layers of river water turbid, and is therefore a very conspicuous feature to the casual observer, forms a very small part of the sediment brought down by the river; and the Mississippi has been observed to appear very turbid during a low stage, at New Orleans, when very little sedimentary matter could be found in the river. It is, indeed, this light matter, so effective in producing turbidity, and constituting the finest portion of the very fine sample of Nile silt, which occupied such a long time in depositing in distilled water. Clay, in reality, constitutes only a small proportion of the whole of the sediment brought down by rivers, amounting, even in the special sample of Nile silt, to little more than one-fifth of the whole, in the Hugli silt to rather over one-seventh, and only about one-tenth in the Danube and Mississippi samples of silt; whilst the finest matter, which is the portion chiefly affected by the action of sea water or solutions of other substances, forms only a small part again of the clay.

Considerably the largest portion of the silt brought down by rivers consists of sand and calcium carbonate, whose settlement is practically unaffected by sea water, and occurs earliest on the checking of the river current on entering the sea. Thus, according to Mr. Guérard, much the greater part of the alluvium brought down by the Rhone consists of fine sand rolled along the bed of the river[1]; and the bar in front of its mouth is composed of sand. In the Hugli also, five of the seven bars stretching across the navigable channel between Calcutta and the mouth of the river are composed of pure sand, and the other two consist of sand with a small admixture of silt due to local erosion of the adjacent banks.[2] Sand, moreover, largely predominates in the Mississippi and Danube silts, and sand and calcium carbonate together constitute considerably the largest portion of the Hugli and Rhone silts; whilst even in the light suspended Nile silt, sand and calcium carbonate comprise nearly three-fourths of the whole.

The bars, accordingly, at the mouths of deltaic rivers are not due, as supposed by Mr. Sidell, to the action of sea water on the river silt, but are the result of the settlement of the sand and calcium carbonate, and occasionally some of the heavier portions

[1] Minutes of Proceedings Inst. C.E., vol. lxxxii. p. 309.
[2] "Report on the River Húgli," L. F. Vernon-Harcourt. Calcutta, 1897, pp. 9-11.

of the clay, owing to the stoppage of the lower portion of the river current on entering the sea. Moreover, the bars across the outlet channels of the passes traversing the Mississippi delta are at a greater distance from the mouth of the pass in proportion to the volume of water discharged by the pass, instead of being formed closer to the mouth in proportion to the greater discharge, as Mr. Sidell supposed would be the case.

The deltas also, though to some extent formed of deposited clay, are composed chiefly of sand and calcium carbonate; and whereas the lighter clayey matter in suspension, if brought down by very pure river water, would be more quickly deposited by admixture with sea water, a portion of it is carried out some distance to sea, over the top of the salt water, before being deposited or dispersed. Moreover, this very light material, on which sea water appears to have most effect, is also most readily carried about and dispersed by any motion of the water, and even stirred up from the bottom by currents and waves; and therefore the deposits produced by the action of sea water on the lightest particles of river silt are much smaller in amount and less permanent in character, except in still water in very sheltered places, than the settlement of the denser portions of silt resulting from the arrest of the river current on emerging into the open sea.

Consequently, though sea water promotes the deposit of the very light clayey matter contained in river silt, under favourable conditions, a property shown by the Author's experiments to be also possessed by certain substances found in solution in river water, there are no grounds for regarding it as exercising the very preponderating influence on the formation of deltas attributed to it by geologists, apparently merely on account of the conclusions Mr. Sidell deduced from his experiments. The chief factor, indeed, in producing bars and the advance of a delta in front of the mouths of sediment-bearing rivers, more particularly when the river discharges into a tideless sea, appears to be the deposit of the heavier silt brought down by the river, and especially the sand rolled along the bed of the river, when the issuing current is checked and eventually brought to rest on flowing into the sea.

(*Paper No. 3200.*)

"On the Use of Monier Pipes as a Pile Covering, and in place of Cast-iron for Cylinder Foundations."

By Ernest Macartney De Burgh, M. Inst. C.E.

In spite of their great density and durability, the Australian hard woods are not proof against the attacks of the *Teredo navalis*, or cobra, and in New South Wales and other Australian colonies it has been customary to protect piles, before use in coastal waters, with a sheathing of copper or Muntz metal. Such a sheathing, however, possesses certain disadvantages, namely: it is liable to injury during the process of driving the piles, and such injury cannot be detected if below the surface; it may be destroyed or injured by objects striking and tearing it, while in water carrying sand in suspension it is quickly reduced in thickness, and is ultimately cut through; and it is costly to replace. As an alternative to metal sheathing, pipes have been used, sunk as a covering round the pile, and subsequently packed with concrete; but ordinary earthenware pipes, while presenting a good hard surface, capable of resisting the *Teredo* and the action of salt water, are not satisfactory, as frequent faucet- and spigot-joints are unsightly and impede the sinking of the pipes, while the irregularity of the pipes makes good jointing difficult, and the material does not lend itself to an improved flush joint. Further, the joints have very little strength longitudinally, which makes it difficult to handle a series of pipes. Even if successfully placed the earthenware is readily fractured by any object striking the pile, or by expansion of the concrete inside.

It appeared to the Author that pipes constructed on the Monier principle, in which steel netting and wires are introduced into the body of the cement forming the pipe, thereby increasing the tensile strength, would be in every way suitable for pile covering, in places where the formation underlying the water admits of their being sunk around the pile to such a depth as to bar the entrance of the *Teredo* below them. These pipes are exceedingly strong to resist fracture, either from internal pressure or by a blow,

and even if cracked they do not fall to pieces; they can also be jointed in such a manner as to have considerable strength longitudinally, which makes them easy to handle, while the joints can be made flush. A most important advantage is that a series of these pipes will withstand the pressure necessary to force them down into the formation, without cracking as earthenware pipes do. It might be suggested that salt water would percolate through the Monier pipes, and would destroy the steel-wire foundation to which they owe their strength; but it has been found by experiment that a column of pipes, 14 feet in height, has remained for 5 months filled with water without showing any sign of moisture on the outside. The Author also considers that, even if the water did reach the wires, there could not be sufficient circulation in the Monier to enable fresh particles of water to come into contact with the wires, to continue the work of oxidation. However, additional precautions were taken to prevent any risk of this occurring, the pipes being freely coated with Stockholm tar, inside and outside, before using, thus effectually choking the pores.

In a traffic bridge over Cockle Creek, near Sydney, New South Wales, five timber piers, having three piles in each, have been protected by Monier pipes, Figs. 1 and 2, Plate 9. The formation is sand mixed with vegetable matter, overlying stiff clay to a depth of about 5 feet, and it was considered desirable that the piles should be protected down to the point where they enter the clay, in order to provide against the possible removal by scour of the soft upper strata. The piles were of ironbark, about 40 feet long, 14 inches in diameter at one end, and 18 inches in diameter at the other end, driven 15 feet into the clay. From the level of the clay to high-water level four hard wood battens were spiked to act as guides for the pipes (Figs. 5, Plate 9), and the piles received a coating of Stockholm tar before being driven. Driving having been completed, a small platform was attached to the pile above high-water level, and upon this was erected, by threading over the head of the pile, a sufficient length of Monier pipes, 21 inches in diameter, to reach from high-water level to the clay bed. The pipes were then jointed with a wire-netting cover and cement, Figs. 3 and 4, Plate 9. While the joints were setting, the capwales were fixed to the piles to bring them into position, and to avoid movement after the pipes were sunk. The platform was then removed, and the pipe casing was lowered by means of hooks under the bottom length of pipe until it rested on the bottom. A jet of water from a 1½-inch pipe was then worked round the bottom of the casing to loosen the underlying material, and

pressure being applied by means of screw-jacks at the top the casing sank easily to the clay bottom. The space between the casing and the pile, having been scoured out with the jet, was filled with clean sand, finished with 9 inches of concrete at the top to form a cap, Figs. 5, Plate 9. The casing presents a neat appearance, and the Author is satisfied that it will prove of great durability, outlasting the pile, which, being of ironbark, may be counted on for a life of 30 years when protected from the *Teredo.*

The pipes used were constructed on the usual Monier principle, being 1⅜ inch in thickness, of cement mortar on a groundwork of steel-wire netting of 1¼-inch mesh and No. 16 gauge wire. The cost of the casing depends almost entirely upon the facilities for carrying the pipes, and if a large quantity were used they might with advantage be made on the work. The Author estimates the cost per linear foot in New South Wales roughly at between 50 per cent. and 100 per cent. greater than that of coppering, and he considers that the effectiveness more than counterbalances the additional outlay in situations suitable for its use, such as that described.

Monier Cylinders in Foundations.—Cast-iron cylinders are largely used in New South Wales for bridge-foundations in salt water, but a great advance in the price of pig-iron directed the attention of the Author to the necessity for finding an economical substitute. The experience gained in the use of Monier pipes as a pile covering pointed to its adoption for cylinders. The chief difficulty anticipated was that of making a strong longitudinal connection between the various lengths of cylinder required to make up each pier. The cylinder finally adopted was 2⅛ inches thick, in lengths of 3 feet 7 inches, with an internal diameter of 3 feet 6 inches, and was made up of one layer of steel-wire netting (1¼-inch mesh and 16 gauge wire) and two spirals of No. 8 gauge steel-wire wound completely round the cylinder, the turns being 1 inch apart. The longitudinal connection was formed by six steel bars 1¾ inch by ¼ inch, placed between the wire spirals. These bars are so arranged that those of adjoining cylinder-lengths can be coupled together by means of a small fish-plate and steel wedges, Figs. 6 and 7, Plate 9.

In sinking the cylinders, the joints were made with red lead to prevent leakage, and it was found that when several segments were joined together they could be lifted without disturbing the joint. A cast-iron cutting-segment was used to protect the bottom edge of the cylinder, and, as a protection against damage by the men's picks, a thin steel-plate guard was provided for the inside of

the cylinder, up to a height of 4 feet, but in practice this was not found necessary, Figs. 8 and 9, Plate 9. The cylinders were sunk through gravel, sand and clay, to a depth of 36 feet below the surface of the water, and as it was found possible to keep them pumped dry if well pressed down by means of screw-jacks, the air-lock was not required. When a satisfactory foundation was reached, the cylinders were filled with concrete in the usual way, the inside surface of the Monier being carefully cleaned to get as good a bond as possible with the concrete. Had an air-lock been required no difficulty was anticipated in attaching it, as the cylinders were quite as true as if cast, and a suitable flange could be readily bolted on to receive the air-lock.

The cost of these Monier cylinders delivered at the site was 24*s.* per foot run, while that for cast-iron cylinders of the same diameter would have been £3 per foot run. These prices, being local and governed by the ruling rate for cement and cast-iron, can only be taken as an indication of comparative value. The Author, however, is satisfied that, especially when cylinders of large diameter are used and such quantities are required as justify the erection of a plant to make them on the site of the works, a large saving may be effected by their use, and he considers them eminently suitable for sinking foundations in soft material.

The Author is indebted to Mr. Robert Hickson, M. Inst. C.E., Under-Secretary for Public Works and Commissioner for Roads in New South Wales, under whose direction these experiments were carried out, for permission to communicate the results, and to Messrs. Gummow, Forrest and Co., to whose assistance the success of the experiments is largely due.

The Paper is accompanied by drawings, from which Plate 9 has been prepared.

(*Paper No. 3211.*)

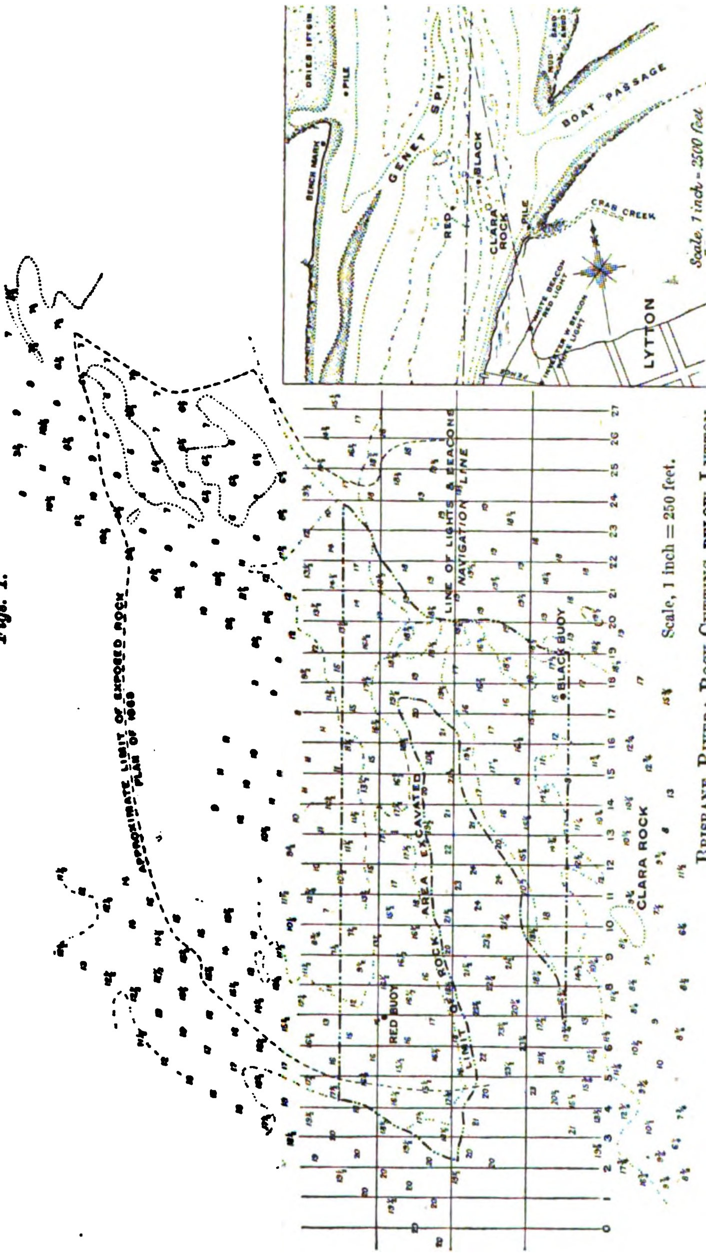
"The Removal of the Lytton Rocks, Brisbane River."

By EDWARD ALEXANDER CULLEN, Assoc. M. Inst. C.E.

A formidable obstruction to the navigation of the Brisbane River is presented by a bar of rock, consisting of a dolorite dyke which crosses the river at Lytton, a few miles above the mouth, in a direction transverse to the navigation line, *Figs. 1.* Originally the depth of water over this bar at low tide was only 14 feet on the navigation line, the rise of spring tides being 7 feet. This depth governed the navigation until 1884, when, by means of a powerful ladder bucket-dredge, the higher and partially decomposed portions of the rock were successfully removed, obtaining an actual gain of 18 inches in depth and an increase in width. In 1889, by direction of the late Mr. W. D. Nisbet, M. Inst. C.E., Engineer for Harbours and Rivers in Queensland, the Author made a detail survey of the rocky area, but further improvement by dredging being considered impracticable the low-water depth remained at 15½ feet until 1896, when the rapidly increasing trade of the port demanded a deeper channel, and the Author was directed to prepare an estimate for an increase of the depth to a minimum of 20 feet at low water. Parliament having made the necessary appropriation, work was commenced in December, 1896, and was carried out departmentally by the Author.

An old iron barge, 70 feet long and 16 feet in beam, was employed, longitudinal sleepers supporting rails to carry the drills being laid along it, and the space below being used for stores, accommodation, etc. Two Ingersoll-Sargeant drills with 4¼-inch cylinders were used, and were supplied with steam at a pressure of 55 lbs. to 60 lbs. per square inch from a boiler which had belonged to a small ladder-dredge. Marlin-wound steam hose was connected to the drill and was used to destruction, a parcelling of sacking giving ample warning of a burst. Each drill was mounted on a cage suspended from the jib of a 30-cwt. crane, and the crane was carried on a wheeled platform standing on the rails. It was

Figs. 1.



Scale, 1 inch = 250 feet.

BRISBANE RIVER: ROCK-CUTTING BELOW LYTTON.

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intended to keep the barge fixed and to move the drills on the rails, but owing to the inadequacy of the back balance-weight to absorb the vibration, it became necessary to stay back the cranes and move the barge the required distance after each pair of holes was drilled. The drills were 20 feet apart, and were worked simultaneously, the holes being spaced 3 feet to 5 feet apart in rows, the distance between the rows being 4 feet; eight holes constituted a set for firing, and in all cases the holes were drilled 2 feet deeper than the depth required. The drill-rods were of steel, octagonal in cross-section, $1\frac{1}{2}$ inch in diameter, and in lengths of 24 feet to 35 feet, the end being set in the form of a cross, $2\frac{1}{2}$ inches to 3 inches in width; the latter width worked much more satisfactorily owing to the less liability to jam.

Blasting gelatine was used throughout, the maximum charge being 3 lbs. per hole. Each charge was prepared by lashing a common calico wrapper containing the gelatine and the detonator to a wooden lath 5 feet to 6 feet in length. Eight charges were prepared at one time, and as each hole was drilled the charge was placed in it; when the last pair of holes was charged the plant was hauled off about 70 feet and the charges were exploded electrically. To remove the sand with which the rock was covered, a 4-inch double-acting pump was employed to supply a powerful water-jet to each drill, a safety-valve placed on the discharge branch preventing any risk of bursting the hose; the necessity for this precaution was demonstrated by the frequency with which the valve acted. The nozzle consisted of a 2-inch wrought-iron pipe, 7 feet long, drawn down to $\frac{3}{4}$ inch in diameter at the end, and was loosely attached by wire loops to the drill-rod. When the overlying sand was more than 2 feet in depth, the bulk of it was first removed by means of a sand-pump dredge. In drilling a hole, the cage, which had sufficient drift below the jib to obviate changing drills for any one hole, was lowered until the rod touched the bottom; the diver then descended, and having first cleared away the sand or mud with the jet, which only occupied a few seconds, made his signal, and the drill was started, the jet being kept in the hole to wash it out. When the desired depth was drilled the charge was handed to the diver, who, when ready to insert it, signalled, and the drill was hoisted up out of the hole; promptness in charging was necessary, as the strong tidal current filled the hole with sand immediately the jet was stopped and the drill lifted. One diver attended each drill, his chief duties being to use the water-jet and to place the charges in the holes. The maximum depth of hole easily drilled and charged proved to be

about 8 feet; at greater depths it was found difficult to prevent some filling up, which caused loss of time in getting the charges home to the bottom.

To locate the position of each hole, cross-section lines, 40 feet apart, were ranged on the river bank transversely to the axis of the channel, and also longitudinal lines, at a distance of 100 feet from the centre line and parallel to it, to intersect these, *Figs. 1*; these marks were sufficiently accurate to indicate a movement of 1 foot in any direction, and a reel of phosphor-bronze wire, graduated, enabled the foreman to locate the holes exactly where required. On a large-scale diagram showing the section lines all holes were plotted as they were drilled. In order to get quickly out of the way of passing vessels, as it was impracticable to divert the traffic, two quick-acting steam winches had to be employed. At night the plant was hauled about 200 feet clear of the navigation-line. The greatest speed of the current at spring tides was 2½ knots to 3 knots per hour, and at that velocity the divers could not maintain their position; the pressure of water against the drill-rods, when the current-speed was greater than 1 knot per hour, created a tendency to jam, but so long as the divers could maintain their position the drills were worked. A small wooden magazine was built on shore, in which to store explosives and prepare charges, those required for immediate use being kept in a hanging safe on the plant. The total number of holes drilled and fired was 6,863, representing 39,187 linear feet of drilling; the best day's work (of 10 hours) was 240 feet. The net quantity of rock removed, measured in the solid from cross-sections, was 27,310 cubic yards. The quantity of blasting gelatine used was 9,750 lbs., equivalent to 0·36 lb. per cubic yard. Omitting the item of plant, the expenses for drilling and blasting amount to about 4*s.* 4*d.* per cubic yard removed.

The rock was raised by means of a large ladder bucket-dredge, as much as 800 tons being raised in 1 day; no special provision was made except to line the shoot with hardwood, but better progress would have been made had rock-lifting buckets been fitted instead of the ordinary bucket of 12½ cubic feet capacity. Some delay was caused by having to straighten out the lips of the buckets with jacks when too much bent. The rock was well broken; the largest piece raised weighed about 4 cwt., but 90 per cent. of the whole was in pieces of less than 80 lbs. Dredging was done in longitudinal belts, 50 feet wide, immediately after the blasting of that belt was finished. The greatest depth of rock removed was 13 feet; when the depth exceeded 8 feet, that amount was first

dealt with, and the whole operation was repeated for the remainder. The dredge was employed for 163 days, giving an average quantity of 167 cubic yards per day, equivalent to about 250 cubic yards barge measurement. At £17 per day, which is the expenditure based on yearly averages, including docking and renewals, the cost of dredging amounted to about 2*s.* per cubic yard in the solid. The carrying plant included at times three large steam hopper-barges, forming the regular equipment of that dredge. It was only practicable to utilize these barges elsewhere occasionally, and when not so employed they attended their own dredge; hence their expenses stand against this work, causing the carriage to appear abnormally high. Their cost, assessed on a similar basis to that of the dredge, *i.e.*, the cost for carriage of the rock, amounted to about 1*s.* per cubic yard of rock in the solid. Adding to these expenses the cost of drilling and blasting, inclusive of plant, the total cost amounts to about 8*s.* 2*d.* per cubic yard.

The total length of rock along the navigation-line was 750 feet, and the width of cutting was 300 feet, giving a minimum depth of 20 feet at low-water of spring tides. The material raised was principally used in the construction of a training-wall about 6 miles above Lytton.

The Paper is accompanied by a drawing from which the Figure in the text has been prepared.

(*Paper No. 3202.*)

"The Chlorination of Gold Ores at Mount Morgan, Queensland."

By Ernest Willoughby Nardin, B.E., Assoc. M. Inst. C.E.

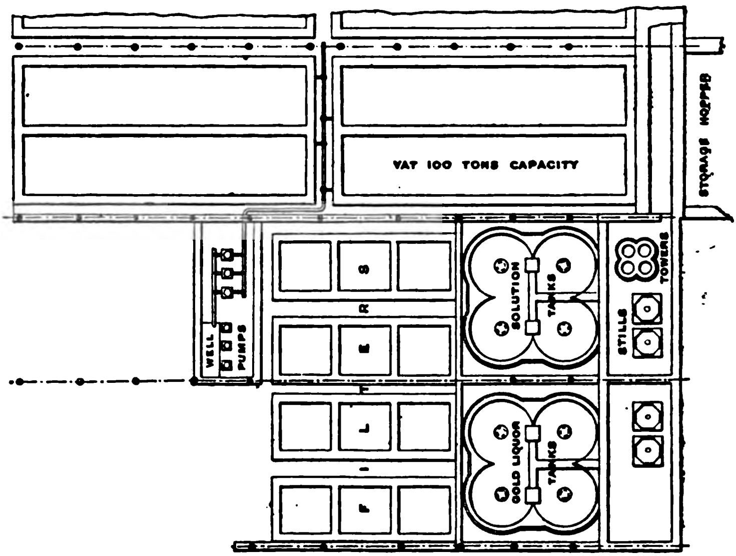
The "Hall-Richard" process of chlorination in use at Mount Morgan, although carried out in vats, differs essentially from the usual method, known as "Plattner's process," in which chlorine gas is passed through the ore, which has been previously damped and placed in vats. The process which it is proposed to describe in this Paper consists in subjecting the ore to the action of a solution of chlorine gas in water, locally termed "solution"; this dissolves the gold, which is subsequently precipitated by passing the liquor through charcoal. The advantages of the process are the ease with which it can be applied, and the very satisfactory results obtained, both in respect of the percentage of gold extracted and the cost of treatment. Altogether, at the different works, about 18,000 tons of ore are treated monthly; but for the purposes of this Paper it will be sufficient to describe the process as carried out at the new "West Works" plant, which treats over 100,000 tons of low-grade ore annually.

The ore sent to the works is taken from the old mine-tips, and consists of a mixture of sinter, kaolin, sugary quartz and a small percentage of hard ironstone. This mixture carries a small amount of sulphur, and when crushed and roasted weighs about 75 lbs. per cubic foot. The average gold contents are 11 dwts. per ton, and the gold exists in a fine state, making it suitable for chlorination. The ore is crushed dry in Krupp ball-mills to pass a 400-mesh screen, is then roasted in steel revolving furnaces, and is stored in main hoppers at the back of and above the vats. For convenience of construction and running, the works were built in four separate sections, working independently, with an auxiliary section containing the engines, boilers, stills, towers, storage-tanks, filters, pumps, etc., for the whole plant.

The chlorination portion of the plant comprises the following:—

Sixteen vats, each of 100 tons capacity, four chlorine stills, one set of towers, four "solution" storage-tanks, four gold-liquor storage-tanks, twelve charcoal filters, three vacuum pumps, three force pumps, and one engine for driving the pumps. The general arrangement of the chlorination portion of the auxiliary section and of No. 1 section is shown in plan in *Fig. 1.* In elevation, the vats and pumps are on the same level, and are 41 feet 6 inches below the roasting-floor. The stills and towers are 14 feet below the same floor; the storage-tanks are 11 feet 9 inches lower, while the filters are 6 feet 6 inches below the

Fig. 1.



Scale, 1 inch = 40 feet.

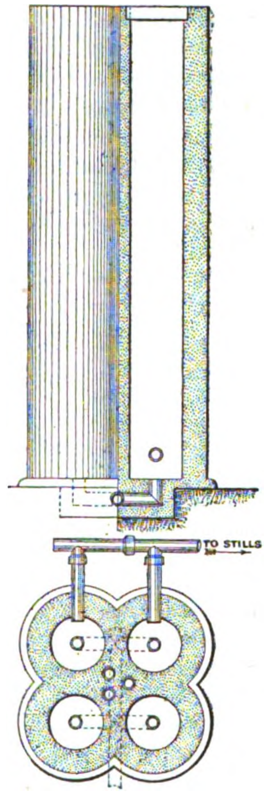
General Arrangement of Chlorination Plant.

tanks. It will be convenient to first describe the arrangement and working of these different portions of the plant, and then to follow the treatment of a vat as it actually takes place.

The Stills.—These are the ordinary imported hydrochloric-acid stills, octagonal in shape, 4 feet 3 inches in width and 4 feet in height internally, and are built of slabs of Yorkshire flagstone 5 inches thick. All the joints are made with round india-rubber, 1 inch in diameter, fitted into grooves in the stone slabs, and the whole is bound together by three rows of iron clips and bolts. No stirrer is used, and the charging-hole is closed by a lead cover

with a water joint. Steam is admitted by two vulcanite pipes, and the gas outlet-pipe leading to the towers is of earthenware, well boiled in a tar mixture. The joints of these pipes, and all others carrying "solution," are made with a mixture of tar, fire-clay and oakum, worked to a thick paste and squeezed into the joints by iron clips and bolts. The chlorine is generated from sulphuric acid, manganese dioxide and common salt. The first is made at the Company's works, from imported sulphur, at a cost of £3 5*s.* per ton; the manganese ore, containing about 72 per cent. of black oxide, costs £5 2*s.* per ton, and the salt costs £4 2*s.* per ton. In preparing this for the stills, the manganese ore is first crushed through a 3,000-mesh screen, is then mixed with the proper quantity of salt, and is further ground in a Chilian mill. The mixture is then put up into bags, each weighing 240 lbs. In charging the still, two bags of this mixture are charged through a funnel pipe from the floor above; the requisite quantity of sulphuric acid is run in from a small storage-tank, fitted with a gauge-glass, and the steam is turned on. This charge takes about 4 hours to work out, and, as the "solution" has to be kept at a certain strength, a small test-pipe is inserted in the main leading from the towers, for the purpose of testing the working of the still; the water supplied to the towers is then regulated accordingly.

Figs. 2.



Scale, ¼ inch = 1 foot.

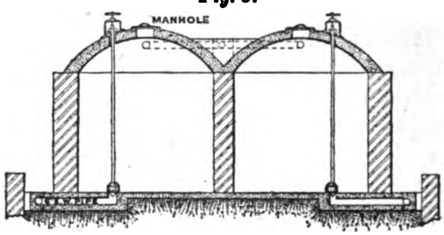
SECTIONAL PLAN AND ELEVATION OF TOWERS.

The Towers.—These are built of concrete, and consist of four circular towers grouped together in one nest, *Figs. 2;* the internal diameter of each tower is 2 feet 3 inches, and the height 20 feet; each tower is packed to within a foot of the top with glass bottles and old assay crucibles. The chlorine gas from two stills enters the bottom of No. 1 tower, passes up to the top, and thence by a pipe to the bottom of No. 2; in its passage upwards it meets a stream of water, which absorbs it and forms the "solution"; the other two stills are

connected in the same way to the remaining two towers. The "solution" outlets are at the bottom and lead into a main, through which the "solution" gravitates to the storage-tanks on the next bench. The towers are faced inside with neat cement, well coated with hot tar and pitch; the tops are fitted with leaden dishes, having a number of 1-inch lead pipes inserted; the latter stand up 1 inch above the bottom of the dish, and are covered by small leaden bells perforated at the lower edge; this forms a water-joint, and at the same time allows the water from the main to pass through to the towers.

The "Solution" Tanks.—There are four of these grouped together in one nest on the bench below the stills and towers. They are built of brickwork on a concrete foundation, and are faced inside with neat cement coated with a mixture of tar and pitch. The domes are of concrete, and each is fitted with a manhole and valve-

Fig. 3.



Scale, $\frac{1}{16}$ inch = 1 foot.

SECTIONAL ELEVATION OF "SOLUTION" TANKS.

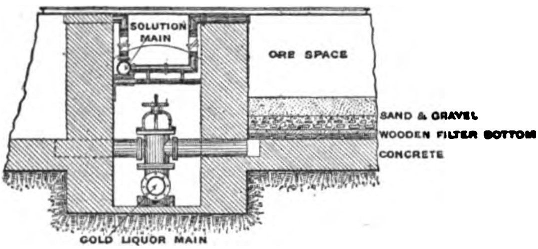
operating gear, *Fig. 3;* the outlets are at the bottom, and the wooden valve-rods pass through the domes to the floor, where the valve seat is formed; each rod ends in a wooden block, faced with sheet india-rubber, and is pressed on to the seat by the hand-wheel and screw at the top. Each tank is fitted with a gauge-glass for measuring the "solution" put on the vats, to which it gravitates through a 6-inch earthenware main. The four storage-tanks for the "gold-liquor" being drawn from the vats are arranged exactly like the "solution" tanks, and their outlets lead to the charcoal filters on the next bench.

The Vats.—These are constructed of concrete, gauged 6 to 1; they are arranged in pairs, a centre wall forming the sides of two contiguous vats; the walls are 2 feet thick, and the floors 18 inches thick. In internal dimensions, each vat is 60 feet long, 12 feet 6 inches wide, and of a depth between 5 feet at the top end and 5 feet 3 inches at the lower end, giving a fall towards the outlet

end of 3 inches in the total length. The walls are constructed first, and when these are stripped the floors are put in; before the work has set too hard all the internal faces are roughly chipped to give a good holding surface for the plastering. This is put on in two thicknesses; the first consists of ½ inch of 2 to 1 grout, and the second of a rendering of neat cement worked to a smooth finish. After about 2 weeks' gradual drying, all the internal surfaces are given a thick coat of a mixture of coal-tar and pitch, well boiled and put on hot.

The filter-bottom consists of 3 inches by 2 inches hardwood bearers spaced 2 feet apart, running with the length of the vat, over which are laid transversely 9 inches by 2 inches hardwood planks; these are fitted loosely, and have a number of ½-inch auger holes bored in them as passages for the liquor. The packing consists of a thin layer of each of the following sizes of gravel:

Fig. 4.



Scale, ¼ inch = 1 foot.

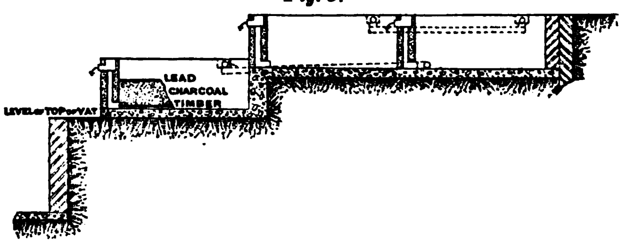
Sectional Elevation of Vat.

2-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch, and on top of this about 9 inches of sand passed through a ⅛-inch sieve, and well washed to free it from dirt and charcoal. The whole of this packing is about 1 foot 4 inches deep, *Fig. 4*. The "solution" main passes along between the two lines of vats, and branches lead to each vat separately, each branch being fitted with a short length of india-rubber piping and a screw clip. The "gold-liquor" main, which is connected to the vacuum pumps, is fitted with a screw-valve and a branch pipe opposite each vat, and by regulating these valves the vats can be put on or off the vacuum at will, *Fig. 4*.

All these "gold-liquor" pipes, and the pumps, etc., are of cast lead with a small percentage of antimony for hardening. A small test-pipe, fitted with a piece of hose and a clip, is arranged in the branch pipe leading to each vat, so that, the main valve being closed, a sample of the liquor coming from the vat can be obtained

for testing purposes. The test-pipes from four vats are arranged at one point so that the testing of the whole of one section can be done there. Lengths of 10 inches by 6 inches timber are let into the concrete on the tops of the side walls of the vats, and these act as longitudinal sleepers for the truck rails. The method of filling and emptying the vats at present is by means of trucks and hand-labour, but it is intended ultimately to employ some form of steam dredge. A timber frame running on the rails, which are laid 14 feet 6 inches apart, from centre to centre, carries four wooden trucks, which are filled from the vat, and then the whole carriage is run out to the tip. By this method six men can empty the 100 tons of heavy wet ore in a shift of 8 hours. The vacuum pumps are of a vertical type, with external outlet- and inlet-valves; the plungers are 10 inches in diameter, and the stroke is 16 inches; they draw the gold-liquor from the vats and discharge it into a small well,

Fig. 5.



Scale, $\frac{1}{16}$ inch = 1 foot.

SECTIONAL ELEVATION OF SET OF FILTERS.

from which the force-pumps lift it to the storage-tanks, on the same bench as the "solution" tanks. The force-pumps are fitted with hardwood plungers, 9 inches in diameter, with a stroke of 16 inches.

The Filters.—These are arranged in four sets, each set being connected to the main from the storage-tanks. The gold-liquor, in entering the first filter of a set, passes down through the charcoal, rises in a pipe leading from the bottom, and flows in at the top of No. 2 filter; here it passes through the second bed of charcoal, and rises as before to flow into No. 3 filter, *Fig. 5.* From No. 3 the waste liquor is either used as a wash water on the vats, or is run on to the tip to clear away the tailings. The pipe connections and valves are so arranged that any filter may be thrown out of use for emptying and re-packing purposes. The filters are built of brickwork on a concrete foundation, and are finished inside with cement plastering and tarring as in the vats; they

measure 10 feet by 11 feet inside, and are 4 feet 6 inches deep. The wooden filter-bottom is formed in the same manner as that of the vats, the timber used being somewhat lighter. In packing a filter, cheese-cloth is first laid over the planking, then finely-crushed charcoal is put in to a depth of 2 feet, and is well rammed in, especially round the walls; thick perforated sheets of lead are then placed on the top and the liquor is allowed to flow in. The charcoal from these filters, when sufficiently charged with gold, is burnt in a reverberatory furnace, and the resulting gold "dust," combined with ash, impurities, etc., is smelted, with suitable fluxes, in a specially-constructed furnace.

In the actual treatment of the ore the method of procedure is the following. The trucks are filled from the main hopper by means of iron shoots through the hopper wall, and are then run over the vat and tipped. No special care is necessary in filling the vats, and when the ore is within 3 inches of the top it is simply levelled, a little being raked to the walls to prevent the solution from making its way down there. The "solution" is then run on, and when the vat is full the valve connecting with the pump-main is opened, and the vacuum, about 5 lbs. per square inch, begins to draw the liquor through. As the level of the solution on the vat becomes lower, fresh solution is run on, and this is continued until the vat is in a certain condition known as "chlorinated," when water is put on, and the vat is kept under vacuum, till, by testing from the pipe below, the wash water shows no precipitate of gold with a solution of ferrous sulphate. The surface water is then siphoned off, and a sample of the residue is taken, the vat being then ready for emptying.

During the first few hours in which a vat is under solution, the liquor from the test-pipe is clear and free from any smell of chlorine gas; later it gets very hot, showing that chemical action is going on in the vat; then, after about fifteen hours, a slight precipitate of gold is given with ferrous sulphate, while towards the end of the treatment the liquor gives a good black precipitate, and smells strongly of free chlorine. If necessary, the amount of free chlorine can be ascertained by titrating with indigo solution. The vat at this stage is chlorinated and is ready for watering. During the time the vat is under water the liquor is occasionally tested to see how the washing is proceeding, and to determine when all the gold is washed out; the vat is then pronounced clean. A chlorination "board" shows the exact condition of each vat. It is the duty of the head tester to try all the vats the last thing before the end of his shift, and to alter the "board"

accordingly. The head tester coming on the next shift can tell at a glance which vats require attending to, and what number of men will be needed for emptying or filling.

The following shows part of the board on 25th January, 1898:—

No. of Vat.	Time "Solutioned."	Inches of Solution.	Time Watered.	Condition.
4	7 a.m. 22nd.	375	2.30 p.m. 23rd.	Clean and sampled.
1	7 a.m. 23rd.	421	10 p.m. 24th.	Strong colour.
3	2.30 a.m. 24th.	380	..	Black.
2	11 a.m. 24th.	164	..	Slight colour.

The tester sees from this that No. 4 is ready for emptying; No. 1 is under water and shows a strong colour or precipitate of gold, and is not likely to be "clean" on his shift; No. 3 has been under solution for about 18 hours, and gives a strong precipitate of gold, but there is no free chlorine yet; No. 2 is in a less advanced condition than No. 3, and only gives a small precipitate of gold. A vat-book is also kept, for reference, in which the main items from the "board" are entered, together with the tonnage, assay of ore and residue of each vat, and the initials of the tester on whose shift each vat was chlorinated or cleaned and sampled. It will be seen that the whole treatment is controlled by the tests made from the test-pipe, and the assay of the residue may not be known for some days after the vat has been emptied; it therefore does not guide the treatment, and is only made as a check on the work of the testers, and for calculating the quantity of gold obtained from each vat.

The following are the principal items in connection with the chlorination at the West Works during May 1898:—

Tons chlorinated	9,852.
Average assay of ore	11 dwts. 13 grs.
" " residue	22 grs.
" extraction	92·06 per cent.
" time under solution	33 hours.
" " " water	35 "
" weight of chlorine per ton of ore .	2·51 lbs.
Cost per lb. of chlorine	5·85*d*.
Average weight of chlorine per cubic foot of "solution"	620 grains.
Still efficiency	72·59 per cent.
Total cost per ton of ore for chlorinating and precipitating	4*s*. 4·58*d*.

The detailed cost of chlorination, etc., at sections 1 and 2 of the West Works for six months ending November 30, 1897, is given in the Appendix.

The treatment of the heavy sulphide ores, mined from the deeper levels, is confined to the Top Works. This ore is a hard and compact bluish quartz, heavily charged with iron pyrites, and weighs about 140 lbs. per cubic foot. The gold value varies greatly, running up to extremely rich ore, but the average sent to the works is about 4 ounces per ton. The sulphur in the raw ore averages about 11 per cent., which, after roasting, is reduced to about 0·15 per cent. The treatment is carried out exactly as described for the West Works, but as the ore is richer and the gold somewhat coarser a larger quantity of solution is required, and the time under solution is correspondingly increased; the total time of treatment is, however, about the same, as the ore is much more porous, and the washing can be completed in a few hours. The following are the chief items in connection with the treatment of sulphide vats at the Top Works during May 1898:—

Tons chlorinated	1,584.
Average assay of ore	4 ozs. 4 dwts. 10 grs.
" " residue	4 dwts. 6 grs.
" extraction	95 per cent.
" time under "solution"	64 hours.
" " " water	6 "
" weight of chlorine per ton of ore	11·47 lbs.
" cost per lb. of chlorine	5·53*d.*
" weight of chlorine per cubic foot of solution	599 grains.

A new plant, to treat 2,000 tons of low-grade sulphide ore per month, is just being completed; it is built on the same lines as the West Works plant, with the exception of the roasting-furnaces, and it is estimated that the total cost of treatment will not exceed 7 dwts. of gold per ton of ore.

The Paper is accompanied by drawings from which the Figures in the text have been prepared.

[APPENDIX.

APPENDIX.

—	£ s. d.	£ s. d.	—	Tons.	s. d.
VATS:—					
General.			Ore treated	28,387	
Wages	2,027 19 2				
Stores	18 14 9				
Cartage	67 0 10				
Water supply	382 8 4				
Assays	58 19 2				
Sand	63 17 1				
		2,618 19 4	Cost per ton	..	1 10·14
Maintenance.					
Wages	121 17 4				
Stores	39 15 8				
Mechanics' work	43 6 7				
		204 19 7	Cost per ton	..	0 1·73
	Total	£2,823 18 11	Total cost per ton	..	1 11·87
STILLS:—					
General.					
Wages	276 11 2				
Stores	5 10 2				
Cartage	81 12 4				
Acid (424 tons 15 cwt. at £3 5*s.*)	1,380 8 9				
MnO_2 (119 tons 7 cwt. at £5 10*s.*)	656 8 6				
NaCl (103 tons at £4 2*s.*)	422 6 0				
		2,772 16 11	Cost per ton	..	1 11·44
Maintenance.					
Wages	56 13 4				
Stores	20 19 0				
Mechanics' work	24 7 10				
		102 0 2	Cost per ton	..	0 0·86
	Total	£2,874 17 1	Total cost per ton	..	2 0·30

Filters:—					
General.					
Wages	122 8 10				
Stores	20 16 2				
Charcoal (17 tons 7 cwt. at £2 5s.)	39 0 9				
Cartage	3 1 2				
Timber	1 18 1	187 5 0	Cost per ton	..	0 1·58
Maintenance.					
Wages	0 15 0				
Stores	3 14 6				
Cartage	0 19 0	5 8 6	Cost per ton	..	0 0 04
	Total	£192 13 6	Total cost per ton	..	0 1·62
Pumps:—					
General.					
Wages	96 0 4				
Stores	39 9 4	135 9 8	Cost per ton	..	0 1·14
Maintenance.					
Wages	29 6 0				
Stores	49 0 5				
Mechanics' work	77 10 7	155 17 0	Cost per ton	..	0 1·31
	Total	£291 6 8	Total cost per ton	..	0 2·45
Electric Light	..	45 6 5	Cost per ton	..	0 0·38
			Total cost per ton for chlorination and precipitation	..	4 4·62

(*Paper No. 3087.*)

"By-Product Coke-Ovens."

By George Blake Walker, M. Inst. C.E.

The successful recovery of by-products from gasworks, and the uses to which tar and ammonia are now applied, have induced a considerable amount of attention to be given to such modifications in the process of coke-making as will enable the same products to be recovered from coke-ovens. The problem has, however, proved to be by no means easy of solution. The results aimed at in the two cases are quite different. In gasworks, an illuminating gas is the prime product, and the coke is reckoned among the by-products, whereas in coke-making the reverse is the case. Gas-coke is not usually suitable for metallurgical purposes, being deficient in density and mechanical strength.

For many years it was considered that the recovery of the by-products from coke-ovens was incompatible with the manufacture of a satisfactory metallurgical coke, but this was completely disproved as long ago as 1866, when Carvès erected his ovens at Besseges, near St. Etienne. It was not until 1881, however, when the subject began to be seriously taken up in Germany, that the practical value of the system came to be realised. In England the Carvès inventions were brought prominently before the Iron and Steel Institute in 1880 by the late Mr. Henry Simon of Manchester, who strongly advocated the value of the system, and introduced many practical improvements; but the innovation at that time met with much resistance from the English ironmasters. An experimental block of Simon-Carvès ovens, erected by Messrs. Pease of Darlington in 1882, abundantly demonstrated the fact that the best quality of coke could be made in these ovens; indeed, this so-called "French" coke acquired a preferential position in the market, for foundry purposes, to the coke made by Messrs. Pease in ordinary beehive-ovens. The Bear Park Coal Company next erected the same class of ovens, with modified apparatus for the recovery of residual products, and plants have since been erected by Sir Bernard Samuelson at Middlesbrough, by the Durham Coke and By-Product Company at Lanchester, and by others.

In a recent article in *The Mineral Industry*,[1] Dr. G. Lunge writes:—"In 1881 Germany awoke to the importance of the Carvès process, and with characteristic skill and enterprise her technologists and manufacturers at once took the lead in the new departure, not merely by patenting a great many improved constructions of coke-ovens fitted for the recovery of by-products, but by setting to work to carry that system into practice. Some hundreds of ovens of the new type were erected within the next few years, and thousands have followed since."

This being the case, it is strange that in England and America so little progress has been made in taking advantage of a process which has been so thoroughly tested. Doubtless three causes have contributed to this: first, a doubt as to the quality of the coke made in retort-ovens; second, a fear lest an over-production of by-products, such as tar and sulphate of ammonia, should result in forcing down the price until it became unprofitable to manufacture them; and third, the considerable cost which the plant involves. All these difficulties have, however, been considered and met by the German coalmasters. It is found that the coke made, though deficient in silvery lustre, is not essentially inferior to beehive coke; that hitherto the increased production of coal-products has been met by an increasing demand; and that the large cost of recovery-plant is proving a highly remunerative investment. These facts having been demonstrated, there can be no doubt that the introduction of plants for the recovery of residuals from coke-ovens will now take place much more rapidly than in the past.

Coal may, for the present purpose, be considered as consisting of three parts—carbon, volatiles, and ash. The object of the coke-maker is to recover the greatest amount of carbon as coke; the object of the gas-maker is primarily to obtain certain of the volatile constituents. The ash, and such sulphur as the coal may contain, are valueless, and, in excess, deleterious components, though a certain admixture of ash is desirable in coke, as it tends to make it stronger and less friable. In the beehive-oven, the heat necessary for coking is obtained from the combustion of the charge itself; to effect this the oxidation of the volatile constituents by the admission of air is required, and in the process between 10 per cent. and 20 per cent. of the carbon is consumed and lost. In the retort-oven the distillation is produced by heat external to the charge, air being carefully excluded from the

[1] Vol. v. p. 181.

coking-chamber, and the volatile bodies, as they disengage themselves from the carbon under the influence of heat, are collected and condensed, the residual gases being utilized for heating the ovens. Thus in the one case the object aimed at is but imperfectly attained, and the by-products are not only lost, but, in the form of smoke, sulphur dioxide and carbonic acid, pass into the atmosphere as noxious fumes.

Attempts have been made to combine the recovery of residuals with the retention of the beehive-oven, the most successful being the process introduced by Mr. A. M. Chambers, of the Thorncliffe Ironworks, near Sheffield. This consists in adding to a standard beehive-oven a clay pipe or flue, running horizontally round the dome of the oven, inside the lining, thus heating the air for the burning of the charge, while the oils are drawn off through holes and pipes in the floor of the oven by means of exhausters. The temperature at which the process is conducted is, however, relatively low, and true tar is not obtained, but hydrocarbons of the paraffin (methane) series, along with olefines. From these, however, several special products (phenols) of considerable value as disinfectants are obtained, as well as lubricating oils and commercial paraffin. These light oils, however, are essentially different from those obtained from retort-ovens, which are worked at much higher temperatures.

When coal is decomposed by heat, the grouping of the molecules in the resulting hydrocarbon compounds varies according to the temperature at which the distillation is carried on. When this is comparatively low, the hydrocarbons formed mostly belong to the paraffin and olefine series; if, on the other hand, the coal has been decomposed at a very high temperature, whilst the olefines and members of the acetylene series still occur more or less, the hydrocarbons of the paraffin class disappear almost entirely, and from them are formed on the one hand compounds much richer in carbon, and on the other hand more hydrogenized bodies.[1] The latter always occur in the gaseous state, methane or marsh-gas (CH_4) and free hydrogen being the principal constituents. The quantity of the valuable constituents of the tar naturally varies with the different kinds of coal used, some coals yielding tar rich in naphthalene and anthracene, while others contain a larger proportion of benzol and phenol.

In addition to the hydrocarbons, coal contains nitrogen to the extent of between 1 per cent. and 2 per cent. Of this, however,

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[1] "Coal-Tar and Ammonia," by G. Lunge, Ph.D. London, 1887, p. 17.

only a small fraction is at present obtained in the form of ammonia, which by combination with sulphuric acid constitutes the ammonium sulphate of commerce. Its value consists in its fertilizing properties, and there can be no question that, at a price sufficiently low, there is an unlimited demand for it for agricultural purposes. In this field it is in competition with sodium nitrate, imported from South America, but, as the nitrate fields have a limited duration, sulphate of ammonia must in time replace it. Sulphate of ammonia is richer in nitrogen than is nitrate of soda, in the ratio of 100 to 78, but the price of the latter is as a rule lower than that of the former. The present value of nitrate of soda is approximately £8 10*s.* per ton, as compared with £11 10*s.* per ton for ammonium sulphate. Besides ammonium sulphate there are other nitrogen products, particularly in the cyanogen group, which will doubtless ere long be successfully recovered from the coking of coal; these will be discussed in a subsequent part of the Paper.

The object aimed at in the design of a by-product oven is to expose the charge to an amount of heat sufficient to effect the distillation with the greatest rapidity consistent with the production of coke of good quality. The heating surface is therefore made as great as possible, and the mass of the charge is comparatively small, in order that it may be rapidly and equally acted upon by the external heat. This is effected in all ovens of this class by making the ovens very narrow, as coke, being a bad conductor of heat, interposes a rapidly increasing obstacle to the distillation of the charge. Although the width of the ovens is varied within certain limits in order to obtain the best results with coals of different compositions, the dimensions of retort-ovens are approximately:—

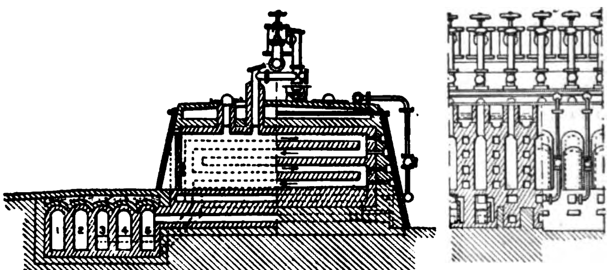
Length	33 feet.
Height	6 feet 6 inches.
Width	1 foot 7½ inches.

Such an oven will hold about 8 tons of ground coking coal, yielding, say, 6 tons of coke per 30 hours, or 30 tons per week. The oven is fitted with a suspended or hinged door at each end, and has in its roof three circular gullets through which it is filled, and one outlet (or two) for the products of distillation to pass out to the condensation plant. When burnt off, the charge is pushed out by means of a steam ram on to a bench on a level with the floor of the oven, where it is quenched. The various types of ovens in use are merely modifications of the same principle. The walls and floors of the ovens contain passages through which burning

gases circulate, and the heat transmitted through the walls between these passages and the ovens effects the distillation of the coal. The difficulty which each modification of the original Carvès idea is intended to overcome is that of equalizing the heat over the whole surface of the heating walls.

The system of flues may be either horizontal or vertical, and either of these systems may be "single" or "double"—*i.e.* a flue may be constructed in the separating wall between two ovens, and be common to both, in which case it is termed "single"; or there may be a pair of flues separated from each other by a midrib or division wall, in which case the term "double" is applied. The advocates of double walls claim that the separation of the flues prevents the lowering of the temperature of the heating gases by radiation when one of two adjacent ovens is being drawn, or re-

Figs. 1.



Scale, 1 inch = 36 feet.

SIMON-CARVÈS COKE-OVEN.

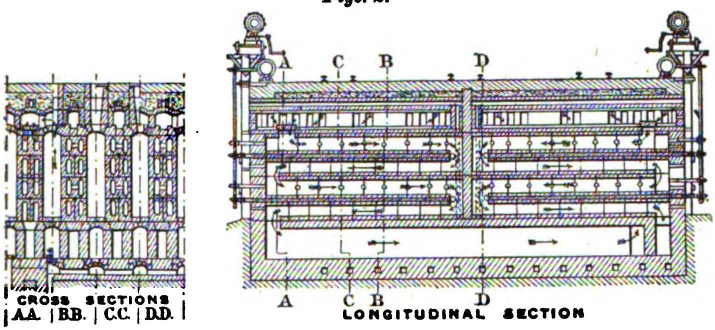
charged, and that the central midrib constitutes a reservoir of heat; they also claim that it facilitates repairs. The advocates of single flues maintain that experience does not bear out these contentions or justify the extra cost.

The system of double flues is most thoroughly carried out in the Semet-Solvay oven, in which the structure of the oven is independent of the heating side-flues, which consist of hollow fire-clay blocks with which the sides of the ovens are lined. These fire-clay blocks can be made very thin, and can be replaced when burnt through without interfering with the general structure of the ovens. In the Brunck oven the principle is the same, but the flues are vertical. In the Simon-Carvès system, which may be regarded as the simplest, the ovens are separated by walls built of large fire-brick quarls about 5 inches thick, four horizontal passages about 8 inches square being built into each wall, *Figs. 1.* The heating

gases course through these passages successively, beginning in the highest and ending in the lowest; but as the gases give off their heat to the adjacent ovens it is necessary to refresh them as they pass onwards and downwards, and for this purpose auxiliary gas-jets are introduced into the second and fourth flues. By means of these jets the heat can be conveniently regulated and a very high temperature can be obtained. With a view to a still further development of the same principle, the horizontal flues of the Collin oven are only carried half-way along the side walls from either end, and fresh gas is not only admitted at the outer ends of the flues, but is conducted to the inner ends by means of pipes, *Figs.* 2.

The Otto-Hoffmann oven has vertical flues, *Figs.* 3. In the case of the ovens with alternating regenerators they are in two groups,

Figs. 2.



Scale, 1 inch = 16 feet.

Collin Coke-Oven.

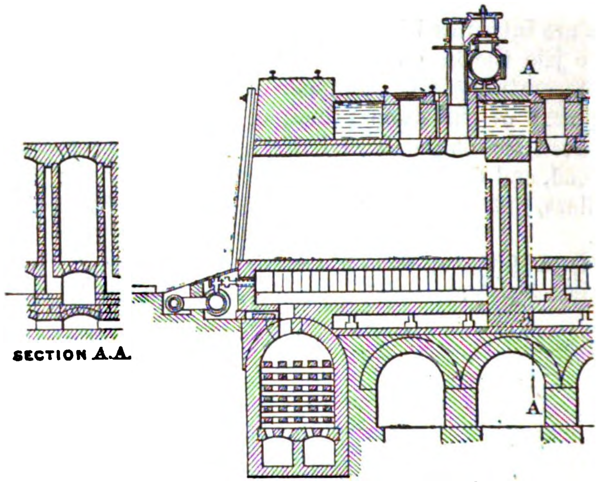
divided at the centre of the oven by a partition; the gases pass upwards on one side of the partition and downwards on the other, in passing from one regenerator to the other.

Reference may here be made to a description of a typical Otto-Hoffmann recovery plant, in a Paper contributed by Mr. F. Simmerbach to the "Zeitschrift für das Berg-, Hütten- und Salinen-Wesen,"[1] which is accompanied by fully-detailed plates. Such an installation, including the large and substantial building in which it is contained, as well as seventy coke-ovens, and the necessary sidings, offices, etc., would cost about £35,000; but a plant to produce the same results may be erected for a good deal less than this amount.

[1] Vol. xliv. p. 402.

In the case of Otto ovens in which the heating is effected by gas burners, the gases pass upwards on both sides of the centre,

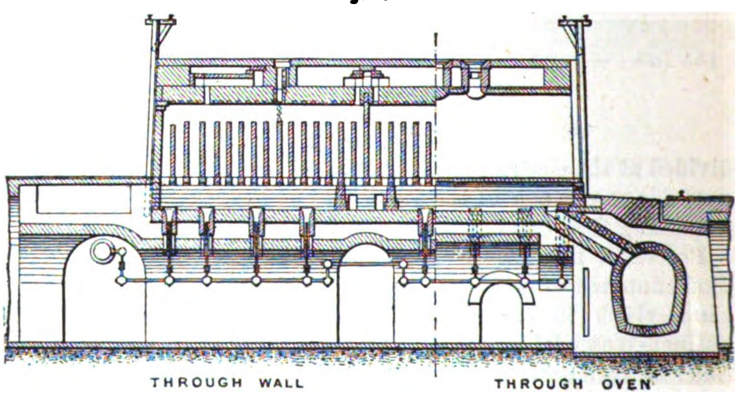
Figs. 3.



Scale, 1 inch = 10 feet.

OTTO-HOFFMANN OVEN WITH ALTERNATING REGENERATORS.

Fig. 4.



Scale, 1 inch = 16 feet.

OTTO-HOFFMANN OVEN WITH BUNSEN BURNERS.

but the central partition gives place to flues by means of which the gases are conducted downwards to a passage beneath the

floor of the oven and thence into the waste flue leading to the chimney (*Fig. 4*). In a modification of this arrangement, the down flues are at one end of the oven instead of in the centre.

The foregoing are the principal differences between the various forms of by-product ovens. Each design has its advocates, and its special advantages in matters of detail, but the general principle is the same in all.

The gases arising from the distillation of coal in closed ovens such as those just described are disengaged most rapidly from the portion of the charge which lies close to the hot sides and bottoms of the ovens; a layer of coke is thus formed round the charge, and as coke is a bad conductor of heat, the efficiency of the oven is gradually diminished as the layer of coked coal thickens. The gases, on being disengaged from the coke, pass upwards to the roof of the oven, and are collected in one or two pipes which lead to the hydraulic main. According to Dr. Tieftrunk the percentage compositions (by volume) of the gases which come off at the various stages[1] of the distillation process are the following:—

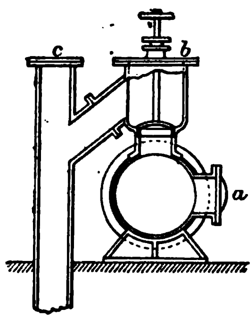
——	First Stage.	Second Stage.	Third Stage.	Fourth Stage.	Fifth Stage.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Heavy hydrocarbons	13·0	12·0	12·0	7·0	..
Marsh gas . . .	82·0	72·0	58·0	56·0	20
Hydrogen . . .	..	8·8	16·0	21·3	60
Carbonic oxide . .	3·7	1·9	12·3	11·0	10
Nitrogen . . .	1·3	5·3	1·7	4·7	10
	100·0	100·0	100·0	100·0	100
Relative volumes in successive stages .	1	0·685	0·387	0·105	..

The composition of the gas will of course vary considerably, according to the quality of the coal used. The gases leave the ovens at a temperature of about 1,100° F. to 1,300° F., but the temperature falls considerably in the hydraulic main, viz., to about 400° F. It is usual to have four openings in the top of each oven, three for admitting the coal and one for the escape of the gases. The latter is about 10 inches in diameter and is fitted with stop-valves. The pipes leading from these communicate with the hydraulic main, the details of which

[1] The stages are proportionate parts of the distillation period, which varies in duration according to circumstances. If the total duration were 30 hours each stage would represent 6 hours.

vary with almost every different kind of oven. In the Otto oven, two large wrought-iron pipes, 26 inches in diameter, extend along the length of the ovens, and lead directly to the condensing apparatus. The deposition of pitch is constantly going on in these pipes and valves, and involves much labour in removal. To facilitate the removal of the pitch, holes (*a*) are provided at frequent intervals, and the valves and vertical pipes are also provided with covers (*b*) and (*c*), *Fig. 5.* The gases being drawn from the ovens by means of exhaust fans, a considerable quantity of fine coal-dust is drawn off with them. With very tender coals this would constitute a serious difficulty if the ovens were charged with dry coal, and it is partly for this reason that the coal is put into the ovens in a damp state, 10 per cent. to 12 per cent. of water usually being present. In spite of damping, a certain quantity of dust passes over with the gases, and the first thing to be done is to get rid of it. To effect this, the gases are passed through vertical wrought-iron cylinders, 6 feet in diameter and 20 feet in height. The gases passing through these cylinders at a low velocity are met by sprays of weak ammoniacal liquor; the greater part of the dust is thrown down, and the temperature of the gases is materially reduced. The water from these cylinders, together with a portion of the heavy tar, flows into a low-level tank, in which the tar and ammonia-liquor separate, in consequence of their different specific gravities. The tars obtained from retort-ovens differ from those from modified beehive-ovens, in which the temperatures are comparatively moderate, in containing aromatic hydrocarbons (benzene, naphthalene, anthracene, etc.), instead of the paraffin series. Their actual constitution varies with the particular coal used, and though the proportions of the different component substances differ with the various samples of coal, their total amount is in general relation to the percentage of volatile constituents which the coal yields on distillation. Coals containing less than 20 per cent. of volatiles are not worth treating.

Fig. 5.



Scale, ¼ inch = 1 foot.

SECTION OF HYDRAULIC MAIN.

The gases leave the dust-precipitation cylinders at a temperature of about 300° F., still laden with tar, the greater part of which is precipitated in the coolers through which they are next passed.

These coolers consist either of large iron cylinders, 20 feet to 30 feet in height, filled with tubes through which a constant circulation of cold water is maintained, whilst the gases pass upwards through the spaces between the tubes, or of a series of horizontal pipes of large diameter, through which the gases pass, and on which sprays of water are kept constantly pouring. The temperature of the gases leaving the coolers is 70° to 80° F. From the coolers the tar flows into the low-level tank already mentioned. The process from this point onwards consists in the separation of the ammonia and the benzol from the gases. The ammonia is recovered by passing the gases upwards through a series of cylindrical towers in which they meet with streams of weak ammoniacal liquor, and finally of pure water, by which the ammonia is completely dissolved.[1] The details of the plant by which this process is carried out vary with every system, but the principle is the same in all. To convert the ammonia into ammonium sulphate, the ammonia liquor is distilled with lime, in stills heated by steam; the ammonia gas is liberated, and is conducted into sulphuric acid, with which it combines. Ammonium sulphate separates out in the form of crystals, which from time to time are ladled out of the tank containing the acid-liquor.

The recovery of the benzol (which is a mixture of benzene and similar hydrocarbons)[2] is effected in one of two ways:—(*a*) By absorption with creosote oils; (*b*) by condensation at a temperature of −94° F.

(*a*) The absorption process consists in passing the gases upwards through a series of towers in which they are washed with creosote oils. These dissolve the benzol, which is afterwards recovered from the creosote oils by distillation. This is effected in cylin-

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[1] Bell washers are used in the Otto plant.

[2] A sample of benzol from coke-ovens obtained by the absorption process is found to have the following composition by weight:—

	Per Cent.
Benzene	85·10
Toluene	11·63
Xylene	1·54
Higher homologues	0·09
Non-saturated fatty hydrocarbons	0·41
Bases (pyridine, etc.)	0·08
Phenols	0·08
Thiophens	0·40
Carbon di-sulphide	0·01
Methylisocyanide	0·0024
Mercaptanes	0·00018
Residue of distillation	0·62

drical stills in which the oils are heated by a steam-coil. The benzol distils over, and is condensed by passing through a coil cooled by water. The last traces of benzol are separated from the creosote oils by passing steam through them.

(*b*) In the refrigerating process, the gases, on leaving the ammonia washers, are condensed to a pressure of 3 to 3½ atmospheres, and are passed through a series of pipes cooled with cold water, where their temperature is reduced to about 50° F. From these coolers they pass to others where they are further cooled to −30° or −40°. After passing through these coolers they are allowed to expand, whereby they reach a temperature of −94°, when the whole of the benzol is reduced to a solid. The expanded gases, before passing away to the coke-ovens, circulate round the second series of coolers, and are thus used to obtain the low temperature of −30°. In this process it is essential that some means be taken to dry the gases before they enter the condensing plant; otherwise the moisture they contain will separate out in the form of ice, which may lead to obstructions in the low-temperature coolers.

After passing through the foregoing processes the composition of the gases, as given by Dr. Lunge[1] (coal from Pluto Mine, Westphalia), is as follows:—

Benzene vapours, C_6H_6	0·60
Marsh gas (methane), CH_4	35·67
Hydrogen, H	52·69
Carbonic oxide, CO	6·41
Carbonic acid, CO_2	1·39
Ethylene, C_2H_4	1·61
Sulphuretted hydrogen, H_2S	0·42
Water	1·21
	100·00

It will be noticed that the heavy hydrocarbons and the nitrogen have disappeared, having been collected in the form of tar or ammonia.

Besides the three primary by-products, tar, sulphate of ammonia, and benzol, there are other valuable constituents which might be recovered. Among these, the one likely to be recovered first is cyanogen, for which in the form of potassium cyanide there is a considerable demand in connection with the gold industry. Sulphur is also sometimes recovered. The waste gases, consisting principally of hydrogen, methane and carbonic-oxide (these three gases constitute about 94 per cent. of the whole), are

[1] "Coal-Tar and Ammonia," p. 58.

combustible, and are employed for heating the ovens as already described, a surplus of heat being available for steam-raising. For this purpose boilers are placed adjacent to the ovens. The spare heat from a block of seventy ovens is sufficient to fire six Lancashire boilers of the usual size (30 feet by 7 feet 6 inches), but the best results are obtained, as with all gas-firing, with water-tube boilers. It will thus be seen that in the adoption of retort coke-ovens, with recovery of by-products, a considerable step is made towards the perfect utilization of the constituents of the coal. Practically the whole of the fixed carbon is obtained as coke, the volatile hydrocarbons are recovered as tar and benzol, and a portion of the nitrogen as ammonium sulphate, while the combustible gases are utilized for heating the coke-ovens and steam-boilers in the most economical and effective manner.

A few practical points in connection with the working of by-product ovens, based on the Author's experience with Simon-Carvès ovens, may prove of interest, though they may not be altogether applicable to all the other systems. The quality of the fire-brick of which the ovens are built is important; the proportion of silica should be high, but not more than 80 per cent., the average temperature in the flues being about 2,000° F. Where, however, a jet of gas is introduced into a flue, the latter should be lined with tiles of almost pure silica, to protect the bricks from the intense heat. The supply of air to the burning gases should be carefully regulated; the amount of air admitted in the first instance should be somewhat less than sufficient to oxidize the whole of the carbon, the excess gas being gradually oxidized as it passes along the flues, thus equalizing the heat as much as possible. The pressure in the ovens caused by the exhausters, and that in the flues due to the chimneys, should be nearly equal, the pressure in the flues being slightly greater than that in the ovens. The regulation of the gas supply requires considerable attention as the pressure is constantly varying with the rate of production of gas in the ovens. This is of course more marked the smaller the number of ovens employed. A gas-holder is frequently used to equalize the pressure, but to be of much use it should be a large one (30 to 40 feet in diameter). The Author is trying a pair of governors such as are used in gas-works. The hydraulic main requires constant attention; with highly bituminous coals it is kept open only with great difficulty; for this reason all valves, pipes, and other parts should be so designed as to be readily accessible for cleaning. In many cases it is necessary to keep a constant stream of thin tar flowing into the

main sections, the valve-seats, and the tar-pipes, to prevent the solidification of the pitch. The hydraulic main should be kept as cool as possible, so that the more volatile constituents of the tar may condense there and prevent the formation of thick tar. The systematic discharging of the ovens is most important. Two ovens adjacent to each other should never be discharged successively; and as far as possible no two ovens in the same section (a section generally consists of six ovens) should be discharged successively. The object of this is to maintain the heat in the ovens as much as possible. The water required for quenching the coke, for cooling the gases, and for supplying the boilers is considerable; the Author finds that 220,000 gallons per day are required for a battery of thirty-five ovens.

The formation of coke is not at present completely understood, and appears to be connected with obscure molecular conditions which vary with different kinds of coal, since all coals are not suitable for this process. The higher temperatures of the retort-ovens, however, produce good coke from some coals which do not coke well in beehive-ovens, and, possibly, the converse may be the case in other instances. More attention is now being paid to this subject and its rapid development appears to be assured.

The Paper is accompanied by tracings, from which the Figures in the text have been prepared.

(*Paper No. 3205.*)

"A Short Description of the Naval Section of the Nicolaieff Dockyard."

By WILLIAM GALLON HUNTER, Assoc. M. Inst. C.E.

THE shipbuilding and engineering works of Nicolaieff cover an area of 1 square mile, and have been constructed with a view to meeting the increasing demands made upon the shipbuilding and other industries in Russia, not only for vessels of the mercantile marine type, but also for ships of war, etc. Hitherto Russia has been largely dependent on the shipbuilding-yards of other countries, and, naturally, there is a strong desire to minimize this dependence by rendering it possible to build first-class vessels in Russia.

The shipyard occupies a site at the west point of the town of Nicolaieff, which is situated on the left bank of the River Bug, about 45 miles from its mouth. The maximum variation of the tide is 2 feet and is controlled solely by the wind. The width of the river here is about 2 miles, enabling vessels to be launched from the slips without the use of anchors or check-ropes, which is an advantage. The river frontage of the yard is shallow for a considerable distance out to the main channel, Figs. 1, Plate 10. In consequence of this shallowness, very extensive dredging operations are being carried out in order to obtain a depth of water of 25 feet, for the purposes of launching and wharfing the vessels in the finishing-basin, Fig. 2. It is hoped that the work of dredging will be completed by June, 1900. (The Ministry of Ways and Communications is occupied with the dredging of the river channel, from Ochakoff up to Nicolaieff, to a depth of 25 feet.)

The building-slips have been laid out on the most modern lines, and are constructed to accommodate vessels of the largest type, six of which can be built at the same time; in addition, there is a sufficient water-frontage available for the launching of smaller craft, such as torpedo-boats, destroyers, etc. Two of the six large building-berths are completely covered in to meet the climatic

conditions, and are specially adapted for the construction of war-vessels; they are equipped in a manner calculated to greatly facilitate the work of erection, etc., Figs. 1, Plate 10. The sides and roof are entirely supported by lattice uprights built upon, and bolted to, solid castings on foundations of stone and concrete, surmounting stacks of piles. The roof does not fall from the centre, as is usually the case, but is composed of transverse divisions, each of which slopes in both directions towards the fore and after ends of the slip respectively, the slopes being covered alternately with glass windows and with corrugated-iron sheets. By this means ample daylight reaches the interior, enabling the workmen to carry on their work with practically the same light as outside. The sides are wholly covered in with corrugated-iron sheets, from the ground upwards, with glass windows placed at suitable intervals. The interior of the sheds is fitted with arc lamps. Water-service tanks of 50 tons capacity, and drain pipes, have been fitted, by which water from the roof is collected. The tanks are placed immediately below the roof of the ship-sheds, and, owing to their great height above the ground, form a very effective hydraulic head for the supply of water to the yard in the event of fire. Pumps are also fitted, so that the service-tanks may be filled from the river.

Six 3-ton electric overhead travelling-cranes are provided, viz., two cranes to each covered berth, and one crane to each adjacent outside berth. The inner cranes travel on longitudinal girders fitted immediately below the roof, while the outer cranes run on rails fitted above the shed roofing, and overhang the adjacent uncovered berths, Section A A, Figs. 1. The cranes have an effective reach of half the width of the berths, or about 38 feet.

The ground upon which the berths are constructed has been reclaimed, consequently the surface ground is unreliable, as it consists of sand and soft mud. This has necessitated extensive piling, in order to provide rigid foundations, not only for the shed-columns, but especially for the building-berths, to obviate distortion of the ships whilst building and launching, due to hogging or sagging stresses induced by the ground sinking under the weight of the vessels; pine piles, 42 feet long and 14 inches in diameter are driven in parallel lines transversely across the berths, and transverse cross-heads of oak, 32 feet long and 14 inches square in cross-section, are fitted and dowelled to the pile-heads. The upper sides of the cross-heads are level with the ground, and upon these the keel-blocks are placed. It is estimated that each of these berths will safely carry 10,000 tons. The amount of dredg-

ing of the finishing-basin and river frontage of the yard which has been required may be judged from the depths indicated in the plan, Figs. 1, Plate 10. The dotted line indicates the boundary of the dredging operations.

On the wharf at the east side of the basin are situated 80-ton sheer-legs, the foundations for which consist of piling, cross-heads, grid and concrete, Figs. 3, Plate 10. A close-pile cofferdam was built round each of the three foundations. The supports for the two front legs are bolted to their respective foundations, and the three foundations are connected by a girder quadrant. The machinery for working the crane, which is electrically driven, is fitted on the inner foundation. Every effort has been made to furnish the various departments of the yard with the most approved and modern tools and appliances, with a view to facilitating the quickest possible execution of work. The usual shipyard machinery is fitted and is electrically driven, with the exception of the hoists, riveting machines, manhole-punching and keel-plate-bending machines, which are worked by hydraulic pressure. The shipyard general offices and mould-loft have been carefully designed, no pains having been spared to render them capable of satisfactorily meeting any demand, whatever may be the extent of the building operations in progress. The mould-loft is constructed immediately over the fitting-, joiner-, tinsmith- and plumber-shops, and measures 300 feet in length by 70 feet in width; it is fitted with arc lamps. These buildings are heated by a service of steam-pipes, fed from the boiler-house, which also supplies the steam for heating the shipyard general offices, a two-storey building surmounted by a photo-room. On the ground floor are the manager's office and offices for the inspectors and clerical staff, while the first floor is laid out for the drawing and other offices of the naval construction department; electric light is fitted throughout.

The shipyard department has just completed an order for thirty small craft for Taganrog, Odessa, Port Arthur and Vladivostock, consisting of a sand-pump, a tug-boat, mud-hoppers and barges to carry cargo, and barges to carry fresh water. The capacity of these craft ranges between 30 tons and 260 tons. The work in hand consists of a cargo-vessel of 1,200 tons dead-weight for the Black Sea and Sea of Azov trade, a 50-foot steam launch, two 90-foot twin-screw passenger-launches for river service, repairs (and new boilers) to two Volunteer Fleet vessels and one merchant steamer, whilst plans are approved for building two transport steamers of 7,200 tons and two cruisers for the I.R.M. of 9,000 tons displacement.

The other sections of the works consist of boiler-shops, bridge-building-shops, wagon-works, engine and mechanical section, iron-foundry, steel-foundry, brass-foundry, pipe-foundry, forge, and model-shops. Each of these divisions is well equipped in modern appliances for the speedy execution of all classes of engineering work.

At present all the departments are fairly well occupied. The boiler-shops have in hand the Belleville boilers for the I.R.M. battleship "Prince Potemkin," the main boiler and one donkey boiler for the "Nijni Novgorod" (Volunteer Fleet vessel), several Cornish boilers, the main boiler and donkey boiler for the s.s. "Oscar," three 300-foot-span railway-bridges, large iron frame structures for works in the interior of Russia, etc. The pipe-foundry has work in hand for the Sevastopol waterworks, etc. The wagon-works has already turned out 1,100 wagons, and has still 3,000 wagons to build to complete the present order.

There are five two-storey houses in the works for the foremen, also a model hospital for the workmen, a large restaurant, a laboratory and a large central store. The central electric lighting station (fitted with Babcock and Wilcox boilers) and the offices of the mechanical section, as well as the restaurant and the laboratory, are situated at the entrance to the mechanical department, the entrance to the shipyard being about $\frac{1}{4}$ mile nearer the river.

The Paper is accompanied by tracings, from which Plate 10 has been prepared.

APPENDIX.

List of Machinery, etc., at Work in the Naval Section.

(The numbers indicate the positions of the machines, by reference to the corresponding numbers in Figs. 1, Plate 10.)

1. Large plate-rolls.
2. Large plate and angle edge-planing machine.[1]
3. Countersinking machine.
4. " "
5. Plate scarphing machine.
6. Double punching machine.
7. Punching and shearing machine.
8. Double punching machine.
9. Mangle.
10. Single-ended punching machine.
11. Punching and shearing machine.
12. Single-ended punching machine with shear-blade face-fittings.
13. " " " " " "
14. Punching and shearing machine.
15. Punching machine (single-ended) with shear-blade face-fittings.
16. Large plate and angle edge-planing machine.
17. Mangle.
18. Horizontal punching machine with double angle-shears.
19. Hydraulic manhole-punching machine.
20. Four-faced punching and shearing machine.
21. Countersinking machine.
22. " "
23. Cold saw.
24. Double punching and angle-shearing machine.
25. Beam-bending machine.
26. Hand machine for punching and shearing.
27. Hydraulic keel-bending machine.
28. Bar-straightening machine.
29. Hand machine for punching and shearing.
30. Four-faced punching and shearing machine.
31. Crane.

[1] No. 2 indicates the temporary position for No. 16.

(*Paper No. 3134.*)

"Irrigation in Victoria."

By George Gordon, M. Inst. C.E.

The colony of Victoria may be considered as consisting of two portions, differing in climate and separated from each other by the Great Dividing Range which crosses the colony from east to west. While the southern part has a fair rainfall and a moderately warm summer, the northern portion is very dry and subject to excessive heat. This portion consists for the greater part of extensive plains, intersected by rivers running generally in a northerly direction towards the River Murray which bounds the colony on the north, and having their sources in the Great Dividing Range. Although some of them, coming from the higher mountainous regions, are permanent, the majority are torrential, and those in the western part never reach the Murray even in flood-time, but are absorbed in marshes or shallow lakes, and are quite dry for many months. Consequently, from the River Goulburn westward the country is subject to severe droughts.

For a long time these extensive plains were only occupied for grazing, but as the ground is well suited for wheat-growing it was quickly taken up when thrown open for selection, and is now chiefly in the hands of farmers occupying between 320 acres and 2,000 or 3,000 acres, and there are also extensive vineyards and orchards.

About fifty years ago, Captain Cotton, of the Madras Engineers, afterwards General Sir Arthur Cotton, R.E., pointed out to some of the squatters who then occupied the northern plains in large grazing areas, the favourable physical conditions of the country for irrigation, and also contributed articles on the subject to the *Australia Felix Magazine*, but, owing to the scanty population and the insecure tenure of the land, nothing could then be done beyond garden cultivation and the cutting of some channels with a view to leading a portion of the flood-waters of the larger rivers into tanks for the supply of stock. No systematic irrigation works were undertaken. In 1856 it was resolved at a meeting of the

Philosophical Institute of Victoria that a Commission be appointed to consider the question of irrigation, but the Author has not been able to find any record of subsequent action, or any Report of the Commission. When the Author went to the colony in 1872, as Chief Engineer of Water Supply, the only proposal for irrigation on an extended or systematic plan was one for the construction of a ship-canal extending from the River Goulburn along the north foot of the Dividing Range, and terminating in the sea near the South Australian border. It was intended to irrigate in its course 6,000,000 acres, but, as was shown by a Report by Colonel Sankey, R.E., in 1871, the scheme was quite impracticable. There were then, however, a few private irrigation works on a small scale; these helped to show the advantages of irrigation where it could be cheaply applied, and it had been practised 30 years previously by private persons in Tasmania.

The wheat-growers on the northern plains were generally men with little or no capital, and to them the expense of clearing and fencing their selections was considerable. Partly from this circumstance, probably, very few of them made any provision by digging tanks for supplying their households and their stock with water during the dry months of the year, and when a long-continued drought occurred they were in great straits, some of them being between 20 miles and 30 miles from the nearest water.

In 1880 the Author and the late Mr. A. Black, Surveyor-General of the colony, were appointed a Board "to inquire and report, first, as to the feasibility of providing, at a reasonable cost, a supply of water to the northern plains for domestic purposes, and for the use of stock; and second, as to irrigation." The Board examined the whole of the northern plains from the River Ovens to the South Australian border, with the exception of the northern part of the mallee country in the extreme north-west of the colony, which at that time was occupied only as sheep-runs. This is an undulating tract of country, the soil being a sandy loam, intersected by sand-ridges, the whole densely covered with mallee (*Eucalyptus dumosa*) and other scrub, with some pines on the ridges, and quite destitute of water-courses, the rainfall being about 10 inches per annum. The Board submitted Reports on the utilization of the natural supply of water in the different river-basins by means of weirs and dams on the principal water-courses, with channels leading from them for the supply of tanks, so placed that by means of them and the storages formed by the weirs water could be made obtainable within a short distance of every holding. It was recommended that Water Trusts should be constituted, with authority to carry

out the schemes by means of money lent by the Government at a low rate of interest, secured by mortgage over the works, and the rates to be levied. While the scope of the works recommended by the Board was limited, as required by the Government, to the supply of water for stock or for domestic purposes, they were, so far as possible, purposely so designed that by enlargements and additions they could be utilized for the gradual introduction of irrigation when a demand for it should arise, and when the population should have so increased as to render its application to the land practicable. The Water Conservation Act (1881), framed to a great extent on the lines of the Board's recommendations, was passed, and many of the schemes recommended were carried out with very beneficial results. Some parts of the colony have been made available for settlement where previously farmers and their stock could not have permanently existed; the occurrence of aggravated water-famines has been averted, and the value of large areas of land has increased between 50 per cent. and 100 per cent.

The Board's two Progress Reports [1] on Irrigation (1882–84), in which it was pointed out that irrigation on a widely-extended scale, though possible, was impracticable with the present population, and in which it was recommended that great caution should be used in undertaking irrigation works, did not meet with the approval of the Government or satisfy the desires of the farmers, then suffering from the effects of a severe drought, and the Board was abolished in 1884. Some attempts to combine irrigation with the domestic and stock supply-works were not successful on account of the Act of 1881 not giving the Government the necessary power to lend money for that purpose, but the subject of irrigation continued to engage public attention, and several landowners began to practise it in a more or less rough and experimental manner. Others had already practised it successfully in favourable localities for years. In 1884 a Royal Commission on Water-Supply was appointed, and a great deal of evidence was taken and published, including a memorandum [2] by the President of the Commission on Irrigation in Western America.

After several amending Acts, an Irrigation Act was passed in 1886 under which Irrigation Trusts could be formed for the

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[1] "Supply of Water to the Northern Plains," published 22nd September, 1882, and 20th March, 1884.

[2] "Irrigation in Western America, so far as it has relation to the circumstances of Victoria," published 1885.

purpose of constructing comprehensive works of irrigation by means of loans from the Government. On the application of a majority of the ratepayers, owning at least one-half the land in a District, and the submission of a description of the proposed works with plans and estimates of the amount of the proposed loan, of the quantities of water available and required, of the area of land that could be beneficially irrigated and its present value, of the annual revenue expected, with other particulars, and, after an examination and report by Government officers, it rested with the Minister of Water-Supply to insert in the Government Gazette, and otherwise make public, a declaration containing the particulars of the scheme and the conditions on which the Trust might be formed and the works undertaken. If the Minister recommended that any part of the works should be considered "national," that is, State works, to be constructed by the Government, the approval of Parliament was required in each case. The Act contemplated the construction of works by the State which would be beneficial or necessary to more than one Trust, and it was provided that no such works should be constructed unless the extent and character of the land to be supplied were such that the interest on the cost of the State works could be paid by the sale of the water supplied to the Trusts, such interest not to begin to accrue till water could be delivered from the head-works. The Trust Commissioners were to be elected from among the shire councillors and the owners or occupiers of land within the Trust District, and no others. Mortgagees of lands had power to petition against the formation of a Trust. The Act provided for a general rate on all land within the Trust area, and, in addition, for a charge for the water supplied by the Trust, as well as for payment by the Trust to the State for water supplied by means of the State works to provide for the interest on the cost of their construction. No loan was to exceed 70 per cent. of the gross value of all ratable property within the Trust District. The interest on the loans was to be ½ per cent. higher than that paid by the Government upon the public loan out of which the loan to the Trust had been made, and in addition 1½ per cent. was to be paid in annually to a sinking fund. It was hoped that under this Act, while the funds required for construction could be obtained at an easy rate, the Government, having the works and the rates and charges as a security for the loans to the Trusts, would be secure from loss. Consequently a large number of Irrigation Trusts were formed, and in most cases the "conditions" show the influence of the land-boom which then prevailed in Victoria, and from the disastrous effects of

which the colony is only now beginning slowly to recover. Applications of the most reckless kind were made for loans for the irrigation of areas far beyond the power of the population to cultivate, and, instead of being checked, were encouraged by the Government, and money was granted in the most lavish manner, those applicants who speculated most heavily being the most favoured. Notwithstanding the checks supposed to be afforded by the Act, large sums of money were lent for the irrigation of a much greater area than that for which water was available, while the rates and charges for water, which were voluntarily incurred by those petitioning for and obtaining the formation of the Trusts, have not been levied by the Trusts, even where water has been obtainable in abundance. In some cases the amount of money lent to the Trusts varied between £1 and £6 16*s*. 6*d*. per irrigable acre, and between £30 and £176 per head of the population of the Trust district. The amounts per acre are by no means excessive; in fact, considering the very easy terms on which the money has been borrowed, the average cost per acre of the works may be considered extremely moderate, but, as the present population cannot profitably irrigate and cultivate more than one-fifth in some cases to one-tenth in others of the whole irrigable area, the present cost to the cultivator would practically be five to ten times this amount. It is not surprising therefore that the receipts of interest from the Irrigation Trusts have been inconsiderable, and much below even the amount demanded after remissions and the deferring of payments, and that the irrigation policy of the Government has been discredited and widely condemned. In 1894 a Royal Commission reported that £978,350 had been expended on the Irrigation Trust works, and that in addition £829,981 had been spent on State works, or £1,808,331 in all, while £165,272 was due by the Trusts to the State for accrued interest. In 1897 the total loans had reached the sum of £1,358,543. Certain amounts of the loans and interest have been placed to a suspense account, and the amount on which interest is now (1898) charged is only £216,566. Still, the amount of interest charged, but outstanding at the end of 1897, was £30,987.

In the Author's opinion the prospects of irrigation in Victoria are by no means so hopeless as these figures would seem to show. The seeming failure is generally due to the fact that in most cases the works have been constructed on a scale suitable to a much greater area of irrigation than the population on the land can at present, or for many years to come, possibly undertake. In forming the Trusts, while careful estimates are framed of the cost

of the works, of the area irrigable, and of the annual charges per acre, supposing the whole area commanded to be irrigated, there does not appear to be sufficient consideration given to the question of how much of that area can be cultivated by the present population with crops sufficiently valuable to bear the rates required to repay the working expenses and the interest on the loan. The irrigation of natural grass for pasture, largely practised in some Trusts, does not and never will bear a sufficient rate to pay interest and maintenance. Other causes of want of success are the want on the part of the farmers of skill and capital in preparing the land for irrigation, and their slowness in adopting any but the roughest style of farming. In some cases the irrigable area of the Trust is far in excess of what the available water can supply, and yet works have been constructed as if the whole area was to be irrigated. Still, in spite of all these drawbacks, it may be expected that eventually, when the population shall have increased sufficiently to cultivate all the land, irrigation will be as beneficial and probably as profitable in Victoria as it has proved to be in other countries, for, as already stated, the cost of construction per acre has been very moderate.

In the extreme north-west of Victoria an experiment was made on the plan of the irrigation colonies in California. This also has, for the present, failed to achieve the success which was confidently expected. A licence to occupy for 20 years 250,000 acres of land was given in 1887 to Messrs. G. and W. B. Chaffey for the purpose of establishing an irrigation colony. Two blocks of 25,000 acres each were to be given to the licensees in freehold when £5 per acre had been expended on them in improvements. For the other 200,000 acres Crown grants were to be issued at the rate of one acre for every £1 expended and a payment to the Treasury of £1 in addition. The licensees sold the land in blocks of 10 acres to settlers, but by the terms of the license no one person was to hold more than 80 acres of fruit-growing land, or 160 acres of agricultural land. The price of the land was £20 per acre, either in cash (when a reduction was made) or in instalments extending over 10 years. The licensees at first cleared the land, making it ready for the plough; afterwards clearing had to be done by the buyer. The licensees had to construct irrigation channels in order to command every holding at its highest point, and to erect the pumping-engines. It is entirely a pumping system of irrigation, the water having to be raised from the River Murray into channels, 30 feet to 75 feet above the river. The country has a suitable fall from the top of the river bank backwards. The channels and the machinery

were to become the property of the settlers, who were also to have a water-right. The maximum quantity of water to be pumped in each month of the year was fixed by the Government. An "Irrigation Company" was formed for the purpose of maintaining the channels and working the pumps, and in this company every acre held represented a share. This was the first undertaking in Victoria by a private firm in the field of irrigation with the object of making profits by the acquisition, improvement, and subsequent sale of land. It thus differed in its object from the Irrigation Trusts already referred to, which are combinations on the part of landowners to improve their own land. The company failed. The most obvious causes of failure were:—want of capital at the beginning; the unskilful arrangement and construction of the supply channels; the sale of blocks of land in too scattered situations, and the consequent large and rapid expenditure in channels, and waste of water in the first years, while the payments for the land were to be spread over 10 years; the inability of some settlers to keep up their payments, the licensees consequently being obliged to borrow money at high rates; the inefficient supply of water to the land, which induced a discontented minority of the settlers to repudiate the payment of the water-rate and to organize an opposition to the licensees, by which they succeeded in stopping the sale of land. The Irrigation Company has been replaced by a Trust which has been granted a small loan by the Government in order to carry out the improvements to the machinery and the channels for which Chaffey Brothers were liable. Of the settlers, some have succeeded, so far, and some have failed. The causes of failure are chiefly:—insufficient capital to start with; inexperience as to the suitability of the different kinds of soil to the various classes of fruit-trees; the inferior quality of some of the trees first imported for planting; damage sustained from soakage, and from the presence of alkaline salts in the soil in some places. Where the settlers have had sufficient capital, and where the proper trees have been planted, there seems generally to have been a fair, and in some cases, a very decided success. The evidence given before a Royal Commission showed that in individual cases the net returns ranged between £40 and £60 per acre, after deducting the yearly cost of cultivation, water, and harvesting. Cultivation costs about £5 per acre and the water-rate is £1. The land with the water-right and channels costs £20 per acre, and is practically unproductive for the first 4 years. In view of the nature of the causes of failure, where it has occurred, there seems to be every

reason to hope for a prosperous future for this settlement. Some errors will be avoided by experience; the soakage is in course of being stopped by lining the channels, and, in all probability, the salts, where they exist in the soil, can be got rid of by drainage.

At present there does not appear to be any tendency to attempt the reclamation by irrigation of land otherwise practically valueless. Excepting on the left bank of the Murray below Swan Hill, where doubtless many favourable sites could be found for fruit-growing in small areas, most of the suitable land for which water is available is already included in Irrigation Trusts, and, as already stated, could fully occupy a much larger population, so that there does not appear at present to be any inducement for private companies to establish irrigation colonies.

The future of the Irrigation Trusts, in the Author's opinion, depends chiefly on the policy pursued by the Government. The Trusts, as at present constituted, have proved to be incapable of working the schemes properly, even in respect to the maintenance of the works and the regulation of the rates, and a stricter supervision on the part of the Government seems absolutely necessary. If the principle of the gradually increasing ability of the Trusts to pay interest on the loans were recognized, and if the amount on which interest is charged were to begin at an amount on which it would not be beyond the power of the population to pay, and were to be periodically increased as the population increases, and if every inducement were offered to the farmers to cultivate such valuable crops as will bear a rate somewhat in proportion to the benefits conferred and the increased value of the land, irrigation would become more popular, and its advantages would be better appreciated. Experience would seem to show that no Victorian Government would be strong enough to take up the work and manage it directly by means of an Irrigation Department as is done in India, but it may be hoped that with a more strict compliance with the Act, and a more equitable system of rating, and when the farmers have learned more about the application of irrigation to the land, the present system of local management may be so improved as to ensure success.

Since the foregoing was written, an Act of Parliament called the Water-Supply Advances Relief Act has been passed, which provides relief to Irrigation- and Water-Supply-Trusts. The amount of capital advanced at the 30th June, 1899, was £1,043,825; the amount written off was £720,252; the interest outstanding was £340,258; and the amount written off the interest account was £337,239.

(*Paper No. 3201.*)

"The Setting-out of Two Tunnels on the Elan Aqueduct."

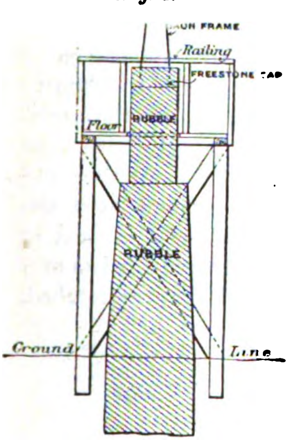
By Arthur William Brightmore, D.Sc., M. Inst. C.E.

In this Paper, the Author presents a description of the methods adopted in setting out two tunnels, one 4¼ miles, and the other 2½ miles in length, on the aqueduct of the Elan Water Supply of the Birmingham Corporation. The tunnels were driven 9 feet 6 inches in height and 9 feet in width, and the various headings met between 15 April, 1898, and 27 January, 1899. The two tunnels are referred to as the Dolau and Knighton Tunnels respectively.

Preliminary Line over the Tunnels.—The line of the tunnels was first set out on the surface of the ground by means of a 5-inch theodolite. For this purpose the stations were marked by 3-inch oak pegs, driven into the ground, and having a small hole to indicate the actual point. In order to see a station from the adjoining ones, a 10-foot pole was fixed upright over the hole in the peg by means of three iron wires attached to the top of the pole and to three small pegs forming a triangle round the larger peg, one of the former being in the line of the tunnel and the other two on either side, to facilitate plumbing; the poles were adjusted vertically in the line by means of the theodolite. After the lines thus fixed had been sectioned and plotted, the positions for the observatories were decided on, those sites being chosen which necessitated fewest observations. The observatories were of two different types. At the intermediate stations, which were only required for checking over the line, the theodolite pillar was simply surrounded by a staging, carrying a floor independently of the pillar, for the observer, *Fig. 1.* At the more permanent points, which had to be referred to when the theodolite was fixed up on the pillars at the ends of the tunnels or at the shafts, the pillar was surrounded by a wooden building, to carry the floor and to protect it from the wind and weather, *Fig. 2.* This design was also used at the stations at either end of the Knighton Tunnel,

but in the case of the Dolau Tunnel it was not convenient to erect a building either at the end shafts or at the shaft near the centre of the tunnel. Moreover, at the latter, and at the west-end shaft, even the erection of pillars would have been a difficult matter, consequently the setting-out theodolite was simply fixed on its tripod over pegs which were checked from time to time. The pillars were built, on solid foundations, of masonry in portland cement, and were finished off with a freestone cap, on which the theodolite was set up. After the observatories were built,

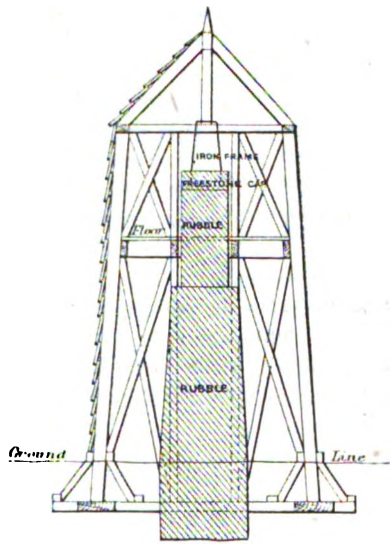
Fig. 1.



Scale, 1 inch = 10 feet.

OBSERVATORY AT INTERMEDIATE STATIONS.

Fig. 2.



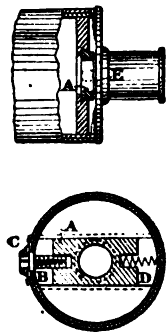
Scale, 1 inch = 10 feet.

OBSERVATORY AT MORE PERMANENT POINTS.

the lines were checked by means of a 9-inch setting-out theodolite, which was also used for extending the lines in the tunnels. On the caps of the stone pillars, iron frames were fixed, having a horizontal bar at the top and so shaped as not to interfere with the setting-up and working of the theodolite, the object of the frames being to enable the exact centre-line to be marked on the horizontal bar; under this mark the instrument was fixed when set up at that station, and at other times this position was occupied by a vertical iron rod, wedged up to the horizontal bar of the frame, for use in referring to that station from the next.

The instrument used was an ordinary 9-inch theodolite, the vertical and horizontal circles being graduated to read by the vernier to 10 seconds, but this graduation was found to possess no advantage for the purpose of lining. The instrument having been set in position on a pillar, the horizontal axis was levelled, if necessary, by means of the striding-level; and the line of collimation was adjusted by reading on to the rod on the adjacent pillar in one direction, turning over the telescope and marking the point indicated on the next observatory; then, after turning the theodolite through 180° and reversing the telescope, reading on to the first point and again turning over on to the second point. If this differed from the first reading, the vertical cross-hair was adjusted until coincidence of the two points was obtained. Great difficulty was experienced on account of the telescope of the instrument, fitted with the ordinary method of adjustment of the cross-hairs, getting out of collimation in carrying it over the rough ground over the tunnels. This was remedied by introducing a special method of adjustment of the cross-hairs, *Figs. 3.* This contrivance consists of a sliding-plate A, on the face E of which the cross-hairs are stretched.

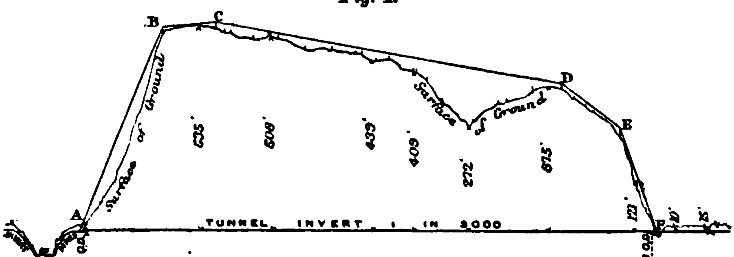
Figs. 3.



Scale, 6 inches = 1 foot

METHOD OF ADJUSTING CROSS-HAIRS.

Fig. 4.



Vertical scale, 1 inch = 500 feet.
Horizontal scale, 1 inch = 4,400 feet.

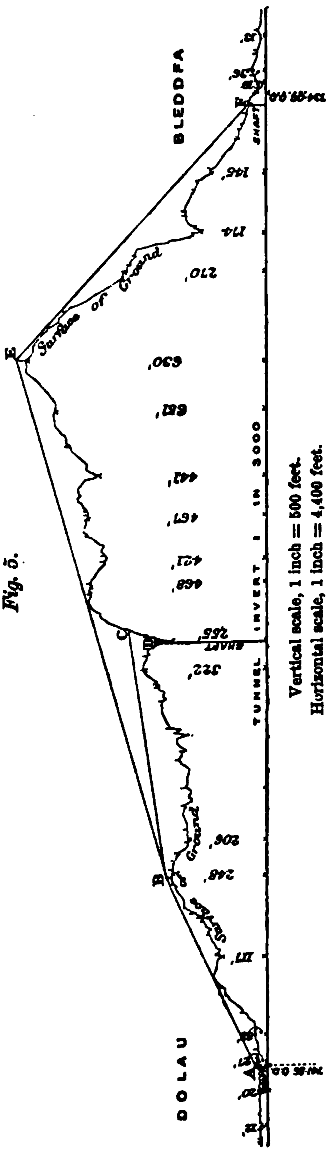
LONGITUDINAL SECTION OF KNIGHTON TUNNEL.

It is caused to slide in a groove in the diaphragm by turning a screw B, which is pressed against a support C by means of a spring D. By this method the screw is opposed by the definite resistance of the spring; consequently it is impossible for the threads of the screw to become partially stripped as so often happens in the

ordinary two-screw arrangement; thus the liability, from this cause, of the cross-hair diaphragm to shake slightly out of adjustment is entirely avoided. Moreover, when adjustment is necessary by turning the screw B with the point of a penknife, the effort required is so slight that it does not disturb the level of the instrument—an advantage of special importance when applied to levels. Thus the cross-hairs can be adjusted with all the accuracy and certainty of a tangent-screw adjustment, and without moving the instrument in any way, so that continual levelling is avoided and much time is saved. By this means the liability of the instrument to continually get out of adjustment, when carted over rough ground or carried in trucks without springs, was quite overcome.

Transferring Line to Inside of Tunnels.—The Knighton Tunnel opens at either end into a valley, *Fig. 4.* It was therefore possible to have pillars at the ends of the tunnel (A and F, *Fig. 4*) at the correct level for seeing into the tunnel, and from which also the pillars B and E respectively could be seen. From these points the line was extended 1,000 yards into the tunnel. When the instrument was set up inside the tunnel, it was seldom possible to see the light at a greater distance than 500 yards, and often less. If delay occurred from any cause, the atmosphere often became too

Fig. 5.



Vertical scale, 1 inch = 500 feet.
Horizontal scale, 1 inch = 4,400 feet.

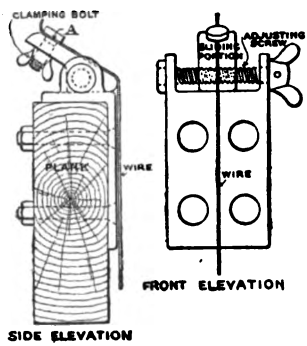
LONGITUDINAL SECTION OF DOLAU TUNNEL.

thick to see, either from the presence of the necessary staff of men, or from the smoke of candles or lamps. Changes of atmospheric pressure were sometimes important, as the headings appeared to be clearer with a falling barometer, owing probably to the air occluded in the crevices of the rock expanding into the tunnel. A ventilating-fan was kept working during the night before the lining was attempted, and also during the operation. In two cases after tunnelling had been stopped, at holiday time, attempts were made to line without previously using the blower, but the accumulation of carbonic acid prevented the lamps or candles burning, and the attempt had to be abandoned in both cases.

The Dolau Tunnel had to be set out from three shafts, one at the west end, having a depth of 25 feet, one at the east end, 50 feet deep, and one near the middle, 300 feet in depth. The positions in which the observatories were erected are indicated on the section, *Fig. 5.* At the west end of the Dolau Tunnel, the position of the theodolite A was so chosen that the observer could focus the telescope on the pillar B, and then, without adjusting anything but the focussing-screw, see both of the wires, thus eliminating the effects of any inaccuracy in the adjustment of the instrument in getting the two wires into the vertical plane containing the centre-line of the tunnel. The distance apart of the wires in the shafts varied between 16 feet and 17 feet. At the Graig Shaft, near the middle of this tunnel, it was necessary to fix the instrument at C in order to see the pillar B and the wires hanging down the shaft. As the distance of C from the two wires was 250 feet, to avoid inaccuracy only the far wire was fixed in the vertical plane containing the centre-line with the instrument at C, and another point D was fixed about half way between C and the far wire. The instrument was next placed near to D and was aligned with that point and the far wire; the near wire was then fixed in position. At the east end of the Dolau Tunnel, as at the west end, the pillar F was fixed so that the pillar in the observatory E, and the two wires, could be seen without moving the telescope. There was more difficulty at this station than at any other, owing to the observatory E being 600 feet above the pillar F, and the ground sloping across, as well as along the line of the tunnel, thus causing trouble from refraction, which was not experienced in other cases. To avoid error from this cause, the readings taken when the atmosphere, owing to the absence of sunshine, appeared to be fairly homogeneous, were considered correct, since in this way a result lying between the extremes was

obtained. There was often considerable difference between the atmospheric conditions on the two sides of the hill on which this observatory was situated, and from this cause difficulty was experienced in fixing the line over the top of the hill. To hang the wires in the shafts, posts were fixed in the ground, clear of the timber of the shafts, near to either end, and a plank was bolted horizontally to them and at right angles to the centre-line. On each plank a brass frame was bolted as near to the centre-line as possible, *Figs. 6.* Each wire was threaded through the hole A in the clamping bolts, and was lowered down to the bottom of the shafts till the plumb-bobs were immersed in the water in buckets placed at the bottom of the shaft for the purpose, when the clamping screws were tightened, the wires hanging freely in a groove over the nose of the sliding portion of the frame. By turning the thumb-screw the sliding portion moved the wire until it was adjusted exactly in position according to the signals of the observer at the theodolite. The weight of the plumb-bobs used in the shafts at the two ends of the tunnel was 6 lbs., while those at the shaft near the middle weighed 10 lbs.; these were found to be heavy enough to give satisfactory results. The wires used were of brass, spun from very fine strands. Fishing-line was tried in place of the wires, but the latter proved to be freer from the tremors which made the fishing-line unpleasant to work with; they also gave much less trouble from stretching.

Figs. 6.



Scale, 1½ inch = 1 foot.

METHOD OF SUSPENDING WIRES.

After getting the wires into line at the top, the instrument was lowered to the bottom of the shaft, and was fixed on a planed balk, so that its line of collimation was in the plane of the two wires. The difficulty experienced in preventing disturbance of the wires by water in the shaft was overcome by surrounding each wire by a trough, open towards the centre of the shaft, thus insuring that the wires were hanging freely. The time of oscillation of the wires in the deep shaft provided an index of this. In aligning the telescope with the wires at the bottom of the shaft, a hand-lamp, the glass of which was covered with tracing-paper,

was placed behind the far wire. The line was extended with the theodolite in this position as far as it was possible to see, generally 500 yards, or 1,000 yards under the most favourable circumstances, after that distance had been driven; but at the Graig, where there was a steam-pump at the bottom of the shaft, it was sometimes impossible to see even a distance of 100 yards.

At the change stations in the tunnels, planed pitch-pine balks, 12 inches by 4 inches in cross-section, were placed horizontally across the tunnel, high enough to allow a person to stoop underneath without touching them. The lights used were Hitchcock kerosene lamps with naked flames, each having a small fan driven by clockwork to keep it supplied with sufficient air. A lamp was placed on the adjacent balk, and its position was adjusted by the theodolite until the flame was in line, as signalled by whistles. A file-mark was then made in an iron dog in the roof of the tunnel, vertically over the light. When the instrument was moved forward, it was fixed on the balk, vertically under this file-mark, and a lamp was fixed under the file-mark at the last station. It may be stated that electric bell-signalling was tried, but whistles were reverted to as being more reliable in wet tunnels. Acetylene gas was also tried in place of kerosene lamps, but the heat produced gave trouble by generating vapour, which at once obscured the light; it might, however, prove more suitable in tunnels of larger section. The centre-lines from the two ends of the first portion of the Dolau Tunnel, $1\frac{3}{4}$ mile long, proved to be within $\frac{1}{2}$ inch at the meeting; in the second portion of this tunnel, $2\frac{1}{2}$ miles long, the centre-lines were 3 inches apart at the junction; and in the Knighton tunnel, $2\frac{1}{2}$ miles in length, driven entirely from its two ends, there was no noticeable deviation between the centre-lines of the two headings at meeting. The Author attributes the greater divergence in the second case to the effect of refraction already referred to. The levels came within the ordinary limit of levelling. Whilst in use on this work the theodolite was carried in a pony cart on a bag of hay, and was slung by its handles to the sides of the cart, over the axle. On one occasion, on steep ground, the pony failed to hold the cart, which slipped backwards till both cart and pony overturned; the method of slinging the instrument, however, saved it from injury. On another occasion the pony, after standing about all day, ran away as the instrument was being placed back in the box, and before the box was closed; the body

of the instrument was thrown out on to the bottom of the cart, and in its fall the tangent-screw was bent, and all the microscopes were either bent or broken; the frame of the instrument, however, proved to be quite undamaged, and the accuracy of its readings unimpaired.

The Author's thanks are due to Mr. James Mansergh, Vice-President Inst. C.E., for permission to communicate the foregoing.

The Paper is accompanied by drawings, from which the Figures in the text have been prepared.

(*Paper No. 3228.*)

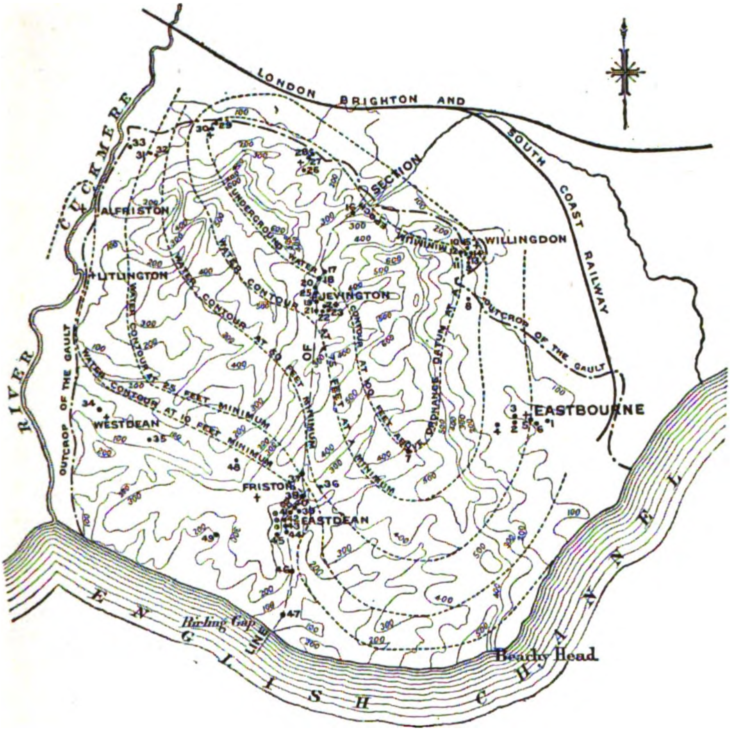
"The Underground Water-Levels of the South Downs between Eastbourne and the River Cuckmere."

By HENRY MICHELL WHITLEY, M. Inst. C.E.

THE portion of the South Downs of Sussex referred to in the following Paper is the extreme eastern knoll, stretching from Eastbourne and Polegate on the east to the River Cuckmere on the west, and from the English Channel on the south to the Weald on the north, being about 5 miles in extent from east to west, and about 6 miles from north to south, *Fig. 1.* The hills rise considerably from the low land around, the highest portions being the eastern and northern escarpments, the ground having a steep slope towards the marshes and the Weald, and a more gradual one to the south and west. The district is bounded on the south by a lofty range of cliffs, of which Beachy Head is the highest part, being 536 feet above Ordnance datum. Northward from this point the escarpment varies between 500 feet and 600 feet, to Willingdon Hill, which has a height of 665 feet above Ordnance datum. Coomb Hill, at the north-east angle, is 638 feet, whilst Wilmington Hill, at the north-west end of the ridge, is 704 feet above Ordnance datum. The principal valley runs from that of the River Cuckmere by Westdean and Friston Place to Jevington Village, where there is a saddleback in the escarpment, about 290 feet above Ordnance datum; here it meets the deeply cut Wannock (or Filching) Glen, leading to the Weald. The other system of valleys has its seaward termination at Birling Gap, and runs inland through Eastdean Village to Willingdon Hill, with branch valleys, or "bottoms" as they are called locally, extending to the eastern watershed.

The geological formation consists of the upper and lower chalk, resting on the gault, the general dip of the beds being towards the south-west. The outcrop of the gault follows the base of the eastern and northern escarpments. From borings recently taken it would appear that the upper greensand overlying the gault is practically non-existent here.

Fig. 1.



Scale, 1 inch = 2 miles.

PLAN SHOWING UNDERGROUND WATER-CONTOURS.

The average rainfall in the district, deduced from a long series of observations to 1894, is shown in the following Table:—

—	Average Rainfall in Inches.	Height above Ordnance Datum in Feet.
Eastbourne (Wilmington Square) .	31·76	39
„ (Osborne House) . .	31·09	12
„ (The Cemetery) . .	31·35	160
Beachy Head	24·22	515
Birling Gap	25·14	50
Eastdean Village	27·11	180

The district is drained by "bournes" or streams, of which the following are the principal:—

On the eastern side, the bourne at Eastbourne rises below the Parish Church at a level of about 80 feet above Ordnance datum; the flow of this bourne has much diminished in recent years and in summer it has practically ceased to flow. The bournes at Willingdon and Lower Willingdon break at about 100 feet above Ordnance datum.

On the northern side, the principal bourne is that in Wannock Glen, the largest in the district; it rises in a deep wooded gorge under Filching Manor House, at a level of 100 feet above Ordnance datum; in winter it has attained a maximum flow of 127 cubic feet per minute. A smaller bourne rises in Broughton Glen, ½ mile to the north-west of this one and at the same level.

On the western side, the River Cuckmere has cut a deep valley through the range of the South Downs, which drains the district so thoroughly that there are few bournes, and these only of small size, breaking at a level of about 10 feet above Ordnance datum.

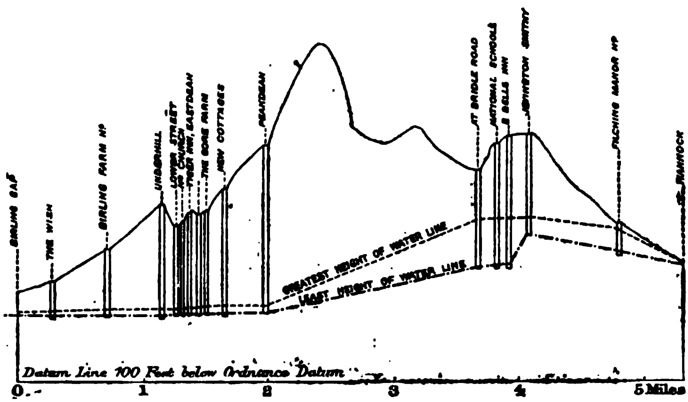
On the southern side, the water escapes by numerous fissures and springs on the sea coast, between high-water and low-water levels, the strongest being those at Holywell, about 1 mile to the west of Eastbourne.

Water Levels.—The results of observations on the height of the water in the various wells in the district, taken by the Author between 1885 and 1899, are summarized in the Appendix, and from these the underground water-contours, showing the lowest levels, have been laid down on the map, *Fig. 1*. The underground watershed roughly follows the highest land at the eastern and northern escarpments. In general, the water slope rises from the sea with an inclination of about 40 feet in 1 mile, thus corresponding with that which obtains in the same downs at Brighton. Inland, towards the marshes and the Weald, the slope is steeper, amounting in places to as much as 100 feet in 1 mile, *Fig. 2*. These underground water-contours roughly follow the surface-contours, but there is one exception. The chalk downs are so drained by the deep valleys of Friston and Eastdean that the minimum plane of saturation is practically level for 1½ mile inland, through the high land at Crowlink, which rises to about 300 feet above Ordnance datum. The range of the water-level in the wells is generally small; but at Jevington, a village in a saddleback on the watershed with a comparatively small drainage area, this range becomes as much as 75 feet.

The underground water finds its way from the watershed to the outlets through the fissures in the chalk, which vary in size between a small crack and a considerable fissure such as that at

Wannock bourne. Some of the wells are situated on considerable underground streams, and these cannot be pumped dry with the ordinary appliances in use. The well at Filching Manor House is sunk on such a fissure, about 100 yards from the pumping-well of the Eastbourne Water Company in Wannock Glen, in the direction of the underground watershed, and although the bottom of the

Fig. 2.



Horizontal Scale, 1 inch = 1¼ mile.
Vertical „ 1 „ = 300 feet.

SECTION FROM BIRLING GAP TO WANNOCK.

well is about 20 feet above that of the pumping-well, from which about 250,000 gallons are pumped into Eastbourne per day, repeated measurements show no sign of its depletion, although the bourne in the valley below the well has now practically ceased to flow.

The Paper is accompanied by two tracings, from which the Figures in the text have been prepared.

APPENDIX.

TABLE I.—MEASUREMENTS OF THE CHALK WELLS IN THE SOUTH DOWNS BETWEEN EASTBOURNE AND THE VALLEY OF THE RIVER CUCKMERE.

EASTERN ESCARPMENT.

Name and Situation of Well.	No. of Well on Plan, *Fig. 1.*	Height of Well-mouth above Ordnance Datum.	Depth of Well.	Height of Water-Surface above Ordnance Datum.			
				Mean Height.	Greatest Height.	Least Height.	Range.
Parish of Eastbourne.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Gildredge Farm . .	1	64·0	62·0	8·0	..	..	..
Finches Cottages . .	2	135·0	75·0	66·0	..	..	..
Coleman's Well, Church St. . . .	3	118·0	58·0	64·0	68·0	60·0	8·0
Upwick Cottages . .	4	145·0	86·0	63·5	66·0	61·0	5·0
Manor House, well No. 1	5	90·0	37·0	56·0	..	..	..
Manor House, well No. 2	6	91·0	45·0	50·0	..	..	..
Peakdean	7	362·0	260·0	109·0	126·0	105·0	21·0
Parish of Willingdon.							
Ratton Farm . . .	8	158·0	91·5	86·0	118·0	69·0	49·0
Red Lion Inn, Willingdon	9	126·0	38·0	93·0	101·0	89·0	12·0
Post-office, Willingdon	10	137·0	55·0	109·5	117·0	98·0	19·0
The Butts, "	11	188·0	91·5	107·0	119·0	98·0	21·0
Willingdon Villa, Willingdon	12	143·0	49·0	105·5	120·0	98·0	22·0
Well of old Post-office, Willingdon Village .	13	146·0	54·0	105·0	117·0	96·0	21·0
Well behind wheelwright's shop, Willingdon Village . .	14	125·0	36·0	98·2	111·0	91·0	20·0
Well at cottage at Old Inn, Willingdon Village	15	125·0	30·0	104·5	116·0	97·0	19·0

TABLE I.—*continued.*

NORTHERN ESCARPMENT.

Name and Situation of Well.	No. of Well on Plan, *Fig.* 1.	Height of Well-mouth above Ordnance Datum.	Depth of Well.	Height of Water-Surface above Ordnance Datum.			
				Mean Height.	Greatest Height.	Least Height.	Range.
Parish of Jevington.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Filching Manor House	16	155·0	52·0	111·0	139·0	104·0	35·0
The Smithy, Jevington Village	17	290·0	161·0	137·4	159·0	130·0	29·0
Well at the Post-office, Jevington Village .	18	290·0	161·4	135·2	155·0	130·0	25·0
Draw-well at the National Schools, Jevington Village . .	19	276·0	198·0	95·7	156·0	81·0	75·0
Eight Bells Public House, Jevington Village	20	285·0	205·0	98·3	157·0	84·0	73·0
Draw-well at turn of Bridle Road over the Downs to Eastbourne, Jevington Village .	21	233·0	155·0	94·6	153·0	80·0	73·0
Well in garden of cottage in racing-stables' yard, Jevington Village	22	238·0	156·0	93·4	154·0	83·0	71·0
Well at cottage opposite training-stables, Jevington Village . .	23	237·0	155·0	97·8	154·0	82·0	72·0
Well at back of cottage above training-stables, Jevington Village	24	243·0	152·0	103·7	153·0	91·0	62·0
Well at the Rectory, Jevington Village .	25	245·0	165·0	84·0	86·0	83·0	3·0
Parish of Folkington.							
Draw-well south of Folkington Church .	26	180·0	78·0	118·0	125·0	110·0	15·0
Draw-well south of old school, Folkington .	27	167·0	68·0	116·0	123·0	109·0	14·0
Well north of old school, Folkington Village .	28	154·0	64·0	114·0	118·0	109·0	9·0
Parish of Wilmington.							
Well at Carpenter's shop, Wilmington Village	29	126·0	32·0	109·0	110·0	108·0	2·0
Well east side of street, Wilmington Village	30	131·0	33·0	122·0	124·0	121·0	3·0

TABLE I.—*continued.*

WESTERN ESCARPMENT.

Name and Situation of Well.	No. of Well on Plan, *Fig. 1.*	Height of Well-mouth above Ordnance Datum.	Depth of Well.	Height of Water-Surface above Ordnance Datum.			
				Mean Height.	Greatest Height.	Least Height.	Range.
Parish of Arlington.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Well at Royal Oak Inn, Milton Village . .	31	85·0	82·0	26·0	28·0	23·0	5·0
Well at cottage, junction of roads, Milton	32	92·0	89·0	33·0	35·0	31·0	4·0
Well at Burghlow Cottages	33	18·0	16·0	10·0	11·0	9·0	2·0
Parish of Westdean.							
Well in Westdean Village	34	44·0	40·0	4·0	..	..	..
New Barn Well . .	35	52·0	54·0	3·0	6·0	1·0	5·0

CENTRAL DISTRICT.

Name and Situation of Well.	No. of Well on Plan, *Fig. 1.*	Height of Well-mouth above Ordnance Datum.	Depth of Well.	Height of Water-Surface above Ordnance Datum.			
				Mean Height.	Greatest Height.	Least Height.	Range.
Parish of Eastdean.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Summerdown . . .	36	239·0	198·0	55·0	58·0	51·0	7·0
Peakdean on the Gore Farm	37	272·0	265·0	10·2	17·0	Well dry.	..
Well at new cottages below Summerdown	38	207·0	204·0	9·7	17·0	5·0	12·0
Well at the Vicarage, Eastdean Village .	39	176·0	180·0	6·5	14·0	0·0	14·0
Well at the Gore . .	40	166·0	164·0	9·0	14·0	4·0	10·0

TABLE I.—CENTRAL DISTRICT—*continued.*

Parish of Eastdean—continued.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Well at cottages opposite the Gore Farmhouse, Eastdean Village	41	162·0	159·0	8·5	14·0	4·0	10·0
Well opposite the Tiger Inn, Eastdean Village	42	167·0	163·0	6·8	1 ·0	3·0	10·0
Well centre of field west of Eastdean Church	43	152·0	150·0	8·0	13·0	5·0	8·0
Well at Lower Street, Eastdean Village .	44	142·0	140·0	7·4	12·0	3·0	9·0
Well at Underhill, Eastdean Village .	45	179·0	178·0	7·3	13·0	2·0	11·0
Well at Birling Farm .	46	109·0	107·0	7·5	12·0	4·0	8·0
The Wish Well* at Birling Gap . . .	47	59·0	60·0	2·0	..	..	..
Parish of Friston.							
Friston Place . . .	48	140·0	138·0	12·0	17·0	10·0	7·0
Crowlink Farm . .	49	195·0	..	10·0	..	..	..

* This well is 23 chains inland from the cliff; it can be pumped dry at low water, but not at high water.

TABLE II.—GAUGINGS OF THE WANNOCK AND BROUGHTON BOURNES.

Date.	Discharge over Weir in Cubic Feet per Minute.	Date.	Discharge over Weir in Cubic Feet per Minute.
WANNOCK BOURNE.[1]		WANNOCK BOURNE (*continued*).	
23 December, 1895	83	12 August, 1897	3
2 January, 1896	85	31 August, 1897	3
7 January, 1896	92	2 December, 1897	3
14 January, 1896	73	15 December, 1897	3
7 February, 1896	54	17 December, 1897	3
27 February, 1896	106	4 January, 1898	5
2 March, 1896	37	BROUGHTON BOURNE.[3]	
2 April, 1896	16		
7 December, 1896	102	7 January, 1896	11
10 December, 1896	106	14 January, 1896	9
11 January, 1897	125	7 February, 1896	8
22 January, 1897	90	27 February, 1896	6
28 January, 1897	90	2 April, 1896	4
3 February, 1897	120	7 May, 1896	3
24 February, 1897	127	14 May, 1896	3
25 May, 1897[2]	18	16 June, 1896	2
3 June, 1897	10	10 July, 1896	1
10 June, 1897	9	6 August, 1896	0·5
17 June, 1897	7	7 December, 1896	9
23 June, 1897	7	17 December, 1896	15
30 June, 1897	6	21 December, 1896	13
8 July, 1897	3	3 February, 1897	16
13 July, 1897	3	8 February, 1897	20
22 July, 1897	3	24 February, 1897	14
27 July, 1897	1	17 April, 1897	6

[1] Gauge-weir 80 feet above Ordnance datum.

[2] In March, 1897, the Waterworks Company commenced pumping at a well sunk in the Glen above the gauge-weir.

[3] Weir at the spot where the Broughton Bourne breaks, 100 feet above Ordnance datum.

TABLE III.—MONTHLY RAINFALL AT TREVELLA, EASTBOURNE, RAIN-GAUGE 5 INCHES IN DIAMETER, 64·00 FEET ABOVE ORDNANCE DATUM.

Month.	1895.	1896.	1897.	1898.
	Inches.	Inches.	Inches.	Inches.
January	..	1·80	2·84	0·91
February	..	0·37	2·94	1·60
March	..	3·25	4·63	1·66
April	..	0·75	2·68	1·16
May	..	0·40	1·19	4·29
June	..	3·54	2·57	1·85
July	..	1·81	0·47	0·33
August	..	1·66	3·60	1·55
September	..	6·52	4·37	0·84
October	..	7·10	0·28	3·22
November	6·76	1·85	2·04	3·06
December	3·53	5·25	3·28	3·24
Total	..	34·30	30·89	23·71

(*Paper No. 3224.*)

"New Method of Dividing Surveying Circles."

By John Coleman Fergusson, M. Inst. C.E.

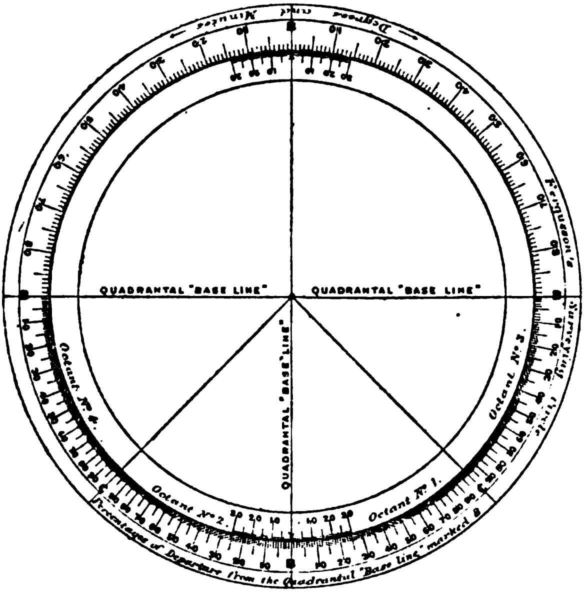
(*Abridged.*)

In making a rapid survey with a tacheometer for many miles in very mountainous and broken country in British Columbia, the tediousness of the calculations, even with the aid of special Tables, led the Author to devise a new method of dividing the circle, which so simplifies the calculations as to enable the surveyor to dispense with the use of Tables.

Whilst the ordinary division into degrees is retained for half the circle, so that the instrument can still be used in the usual manner, the other half is divided in a novel way, each of the four octants of the semicircle, or arcs subtended by angles of 45°, being divided into a hundred unequal divisions, commencing in every case from one of the main quadrantal lines, B, of the circle as zero, *Fig. 1.* The principle on which these octants are divided may be readily understood from the following description and diagram, *Fig. 2.* The length of a tangent to a circle between its tangent point B, at the extremity of a radius A B, and the point D where it is intersected by another radius A C produced, making an angle of 45° with the radius A B, is equal to the radius of the circle, or B D = A B, *Fig. 2.* Then dividing the tangent B D into one hundred equal parts, and drawing straight lines from the centre, A, of the circle, through the octant arc B C to the divisions on the tangent as represented for every ten divisions in *Fig. 2*, the octant B C, or circular arc subtending an angle of 45°, is divided by these lines into one hundred unequal divisions, decreasing consecutively in size from 34 minutes 23 seconds at B, to 17 minutes 16 seconds at C, but each subtending equal lengths along B D, of one one-hundredth of the radius. This is the method which has been adopted for dividing the octants of half the circular plate, *Fig. 1*, commencing in each case from a main quadrantal radius, such as those marked B, *Fig. 1*, or A B, *Fig. 2.* By dividing the circular plates of a theodolite in this manner, the horizontal distance

from the instrument, measured along the base-line, of a staff held horizontally or vertically at right angles to the direction of the

Fig. 1.



DIVISION OF CIRCLE.

base-line coinciding with a main quadrantal radius, is readily obtained by observing the space on the staff covered by the difference between two readings on the staff with the theodolite, in turning it through a definite number of these special divisions, and multiplying this observed length by 100, and dividing it by the number of divisions through which the theodolite was turned. The perpendicular distance, moreover, of the staff from the base-line, either horizontally or vertically, is simply the percentage of the horizontal distance of the staff from the instrument along the base-line, as indicated by the number of divisions along the plate from the zero, or in fact the reading, corresponding to the line of sight of the telescope directed to the staff.

Fig. 2.

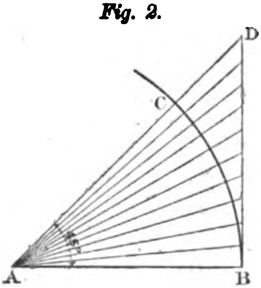


DIAGRAM SHOWING METHOD OF DIVIDING CIRCLE.

Angles can be read on both halves of the circle, either in terms of a percentage of departure, or in degrees, *Fig.* 1; and a surveying instrument provided with this circle is thus converted into a telemetric instrument, as shown by the following examples:—

Fig. 3.

DIAGRAM ILLUSTRATING APPLICATION OF CIRCLE.

Examples of the Use of the New Circle.—If, on a staff held horizontally at right angles to the base-line, three divisions on the circle subtend 4·23 feet, then the distance of the staff from the instrument along the base-line is $\frac{1}{3}$ (4·23 feet × 100) = 141 feet. The departure of the position of the staff is the percentage of this distance indicated by the index on the octant; if this reading is, say 20, the departure is 141 feet × 0·20 = 28·2 feet. To take the direct distance of a station with the azimuth circle, the station is sighted through the telescope with the horizontal plates clamped at zero; then the line of sight is over the base-line. The level of the station is the horizontal distance along the line of sight multiplied by the percentage read on the octant from a horizontal base-line on the vertical circle, with a correction for the height of the instrument.

The direction, latitude, and departure of a course can be obtained with the new circle in the following manner. Having set the quadrantal base-lines to correspond with the cardinal points of the compass, suppose that an object marking the line of the course lies to the east of the north base-line, and its direction reads 14 divisions on the adjoining eastern octant, then the direction of the course is 14 feet east for every 100 feet north, or 14 per cent. east of north, and can be at once set out with any scale on a plan. To find the latitude, the staff is held horizontally over the object, pointing east and west, and therefore at right angles to the north base-line; and supposing the telescope, directed on the object, when turned through three divisions on the octant subtends 9·75 feet on the staff, the distance along the north base-line, or the latitude of the course, is $\frac{1}{3}$ (9·75 feet × 100) = 325 feet. The easting or departure is 14 per cent. of the distance along the north base-line, or 14 per cent. of 325 feet = 45·5 feet.

The application of the new surveying circle in simplifying observations taken at sea is indicated by the following example.

Setting one of the base-lines in the line of the ship's course A B, *Fig. 3*, it is required to find the distance, A B, the ship has to steam to get abreast of a lighthouse C, and the distance, B C, at which she will pass the lighthouse. The bearing of the lighthouse at A is, say 10 divisions on the octant, east of the ship's course; and, after having steamed 10 miles by the log to F, the bearing is, say 14 divisions to the east. Now the number of divisions subtended by the angle A C F is equal to the divisions on the octant subtended by the angle B F C less those subtended by the angle B A C, or $14 - 10 = 4$ divisions. But the departure at F from the first bearing A C, or F I, is 10 per cent. of the distance A F, namely, 1 mile, and this distance, F I, may be regarded as the space on the tangent F H covered by the 4 divisions subtended by the angle A C F, so that the distance along the base-line C H is $\frac{1}{4}$ (1 mile $\times$ 100) = 25 miles, which is also the length B F; and therefore A B, the distance steamed, = 35 miles. The length B C, accordingly, is $\frac{25 \text{ miles} \times 14}{100}$ or $\frac{35 \text{ miles} \times 10}{100} = 3 \cdot 5$ miles, the distance off the lighthouse at which the ship passes.

The Paper is accompanied by four photographs and a diagram, from which the Figures in the text have been prepared.

OBITUARY.

JAMES RICHARDSON FORMAN died at his residence, Craig Park, Ratho, Midlothian, on the 8th July, 1900, in his 78th year. He was a native of Nova Scotia, to which colony the family emigrated from Coldstream, in Berwickshire, in 1780. In 1841 he came to Glasgow, and, after serving an apprenticeship to Mr. Niel Robson, he was appointed in 1845 Resident Engineer on the Wilsontown, Morningside and Coltness Railway, then in course of construction, in connection with which serious difficulties had arisen between the Company and the contractor. After successfully completing and equipping that railway, Mr. Forman remained as Manager until 1851, when he was appointed Manager of the Glasgow General Terminus Railway, which post he held for two years. He then accepted a commission as Government Engineer for the province of Nova Scotia, where he served for six years.

Returning to Glasgow in 1860, Mr. Forman entered into partnership with Mr. Robert Robson and Mr. McCall, under the style of Robson, Forman & McCall, and took an active interest in railway development in Scotland. Among the undertakings with which he was connected were the Greenock and Ayrshire and Wemyss Bay Railways, the Blane Valley line, the Busby and East Kilbride, Stobcross, Kelvin Valley, Milngavie and Aberfoyle Railways, and Gryffe Waterworks, Greenock. Latterly Mr. Forman did not take active interest in business, although he remained Chairman of the Aberfoyle Slate Quarries Company, and, until recently, of the Edinburgh American Land Mortgage Company, which post he had held for over twenty years. He was also a Director of the Arizona Copper Company. Since 1880 he resided at Ratho, and took a lively interest in all connected with that village, having been Chairman of the local School Board and Parish Council.

Mr. Forman was elected a Member of the Institution on the 1st May, 1866.

EDWARD GARLICK, born in 1822, served his engineering apprenticeship to Mr. Philip Park, of Preston. His first important engagement was that of Resident Engineer on the Fleetwood, Preston and West Riding Junction Railway, which post he held for

three years, being responsible during that time for the construction of the tunnel under the town of Preston. He then acted for two years as an assistant to Mr. Park, and in 1851 joined the firm of Park, Son and Garlick, and carried on business in Preston.

Among the works executed by Mr. Garlick may be mentioned the Sea Wall, Carriage Drive and Promenade at Blackpool, and the construction of many miles of embankment on the Lancashire coast. As Engineer to the Ribble Navigation Company he constructed the old quays and river training-walls, and reclaimed from the sea several hundred acres of land. He was appointed Engineer to the Ribble Navigation after the Corporation purchased the undertaking, and he subsequently designed the present dock, tidal basin and river diversion, and the dredging plant, but owing to ill-health he was compelled to relinquish the work and to retire from business for a time.

Mr. Garlick was for many years Engineer and Steward to the Corporation of Preston, in which capacity he carried out many town improvements, including the cattle markets and the large covered market, as well as various works for the water-supply of Preston. In 1868, a very dry season, the storage in the reservoirs was all but exhausted. To meet this emergency, Mr. Garlick erected two engines which pumped water out of the Hodder, the only available supply, the water being conveyed down an aqueduct 7 miles long, with little fall and one incline, the entire work being completed in a few days.

Mr. Garlick constructed many waterworks reservoirs, and at the time of his death, which took place at Preston on the 13th January, 1900, was Engineer to the Fylde Waterworks. For many years he was frequently engaged as a witness in arbitration cases and before Parliamentary Committees.

He was elected a Member of the Institution on the 8th January, 1861.

HARRY PASLEY HIGGINSON, born in 1838 at Thormanby, Yorkshire, was educated at the Collegiate School, Leicester. On leaving school he served an apprenticeship to Sir William Fairbairn, from 1855 to 1859, during which time he became acquainted with all kinds of iron-work and the details of the drawing office. From October, 1859, to November, 1861, he was engaged in Russia on the construction of the Riga-Dünaburg Railway, after which he was appointed in March, 1862, to the Government Staff of the

Mauritius railways. There he was employed for one year in laying out, levelling and surveying the Midland line, and was subsequently appointed District Engineer of the third section of that line, which position he occupied until October, 1865, when the line being opened for traffic, one half of it remained under his charge. In January, 1867, Mr. Higginson was appointed a second class Executive Engineer on the Staff of the Madras Irrigation and Canal Company, and was occupied for the following twelve months in revising the plans and estimates of the tenth section of the works. He then became Assistant Executive Engineer on the second section, which comprised very heavy works, and after their completion in October, 1868, was transferred to the eighth section, on which a great part of the heavy masonry locks were constructed under his direction. In May, 1869, he was promoted to first class Executive Engineer and was entrusted with the tenth section, including, besides locks and head-work, the Pennair anicut or weir, 2,240 feet in length, which was finished on the 1st June 1871, when he returned to England.

In 1872 Mr. Higginson entered the service of the Government of New Zealand, and in September of that year was appointed Superintending Engineer, his duties including the supervision of all the railways and other public works under construction by the Government in the South Island. He held that post until 1878, when, the exigencies of the public service requiring a reduction of the engineering staff, his engagement was terminated. Mr. Higginson then began to practise on his own account in Dunedin, and among the works carried out by him in New Zealand may be mentioned the Waimakariri Gorge Bridge, the Lyttelton Waterworks, the Waimea Plains Railway, the Kawarau Suspension Bridge, and the Balclutha Bridge. For his account of the Kawarau Suspension Bridge,[1] presented to the Institution in 1882, he was awarded a Telford Premium. In the same year he was appointed Chief Engineer, to design and superintend the construction of the Wellington and Manawatu Railway, which was successfully completed in November, 1886. In 1889 he was appointed Engineer and Manager of the Wellington City Gasworks, which posts he held until ill-health compelled his retirement in 1898.

Mr. Higginson died at Wellington on the 26th February, 1900.

He was elected an Associate of the Institution on the 5th February, 1867, and was transferred to the class of Members on the 5th December, 1871.

[1] Minutes of Proceedings Inst. C.E., vol. lxviii. p. 248.

ROBERT JACOMB-HOOD, eldest son of the late Mr. Robert Jacomb, who assumed subsequently the name of Hood, of Bardon Park, Leicestershire, was born at Riseley, in Bedfordshire, on the 25th January, 1822, and received his preliminary education at Christ's Hospital. To meet the wishes of his father he was specially prepared, on leaving school, with a view to the Bar as a profession, and kept several terms at Trinity College, Cambridge, in 1840 and 1841. He had, however, been thrown previously with young men who were engaged on railway construction in the Midlands, and by them he was imbued with a desire to become an engineer. His father's objections having been overcome, Robert Jacomb-Hood, in the year 1841, became an articled pupil of Mr. George Watson Buck, then Chief Engineer, in conjunction with Robert Stephenson, of the Manchester and Birmingham Railway. Under Mr. Buck, Mr. Jacomb-Hood became Assistant on the Holmes Chapel length of the line to Mr. William Baker, afterwards Chief Engineer of the London and North Western Railway; and on the Crewe length to Mr. W. H. Barlow, Past-President. When the line was opened to Crewe in 1843 Mr. Jacomb-Hood was engaged as Chief Assistant by Mr. Buck, who had then severed his connection with the Company to take private practice in Manchester. In that capacity he was employed among other works in the rebuilding of the New Bailey Bridge at Salford. Subsequently he again became an Assistant to Mr. William Baker on the engineering staff of the Manchester and Birmingham line, having been appointed for the construction of the Macclesfield branch. Between 1844 and 1846 he acted as Resident Engineer on the Manchester, South Junction and Altrincham line.

In 1846 Mr. Jacomb-Hood was appointed Resident Engineer to take charge of the whole of the system of the London, Brighton and South Coast Railway Company. This was the beginning of a connection which lasted in one form or another for fifty-four years. In the early days of his appointment as Engineer to the Brighton Company Mr. Jacomb-Hood was engaged chiefly in completing stations and works in progress, in arranging maintenance contracts, and on the construction of the new London Bridge Station, and of the Bricklayers Arms Goods Station. He also laid out and completed the Newhaven, Eastbourne and Hailsham, Epsom, Croydon and Wandsworth, Littlehampton and Steyning branches.

In 1850 Mr. Jacomb-Hood was awarded a Council Premium of

Books by the Institution for his "Description of the Lift Bridge over the Grand Surrey Canal, on the line of the Thames Junction Branch of the London, Brighton and South Coast Railway,"[1] and in 1858 he obtained a Telford Medal for a Paper entitled "The Arrangement and Construction of Railway Stations."[2]

Between the years 1850–60 the Brighton Company were fully engaged in developing their property, and it fell to Mr. Jacomb-Hood within that period to lay out the Crystal Palace branch, the East Grinstead branch, the Midhurst branch, the Lewes and Uckfield, and Shoreham and Henfield lines—while at the same time he was engaged on the Victoria Station project and the enlargement of Brighton Station, as well as on other heavy works.

So severe became the pressure of Parliamentary work that, in September, 1860, Mr. Jacomb-Hood resigned the post of Resident Engineer to the Brighton Company, retaining their Parliamentary and new works, and took up private practice in Westminster. The Mid-Sussex and South London lines were carried out by him at that time, as well as the Croydon and Balham, the Horsham and Guildford, and Horsham and Dorking lines, the Seaford Extension, the Brighton, Uckfield, and Tunbridge Wells, and the Bognor branches. In 1863, in conjunction with Mr. G. P. Bidder, he was busy on the Peckham and Sutton and Leatherhead and Dorking lines, and on Newhaven Harbour Improvements, as well as on plans for the Hadlow line, East London Railways, Axminster and Lyme, Southend and Malden, Ouse Valley and Hastings, Kingsland and Finsbury lines, and tramways at Southsea.

Mr. Jacomb-Hood was joined by his cousin and former pupil, William Jacomb, as partner in 1865, and together they deposited schemes for railways in many parts of the country, including the Surrey and Sussex, Hornsey and Kingsland, West Kent, Chichester and Midhurst, Peckham and Dartford, and Norwood and Crystal Palace High Level lines, and a branch line from Bridport to Lyme. Works undertaken subsequently to the above date include the preparation of the details of the ironwork for the National Gallery and the re-building of Portcreek Viaduct.

In 1869 Mr. Jacomb-Hood became a Director of the Crystal Palace Company, and in the following year he dissolved partnership with Mr. William Jacomb, on the latter's appointment as Chief Engineer to the London and South Western Railway Company. He took an active part in the construction and organization

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[1] Minutes of Proceedings Inst. C.E., vol. ix. p. 303.

[2] *Ibid*, vol. xvii. p. 449.

of the Crystal Palace Aquarium and in the affairs of the Company generally, until he resigned his seat at the Board in 1879. In 1870 he joined the Board of the Anglo-Maltese Hydraulic Dock Company, and was employed on several occasions in investigating the affairs of that company at Malta. In 1872 he was commissioned by the late Mr. Samuel Laing, then Chairman of the Brighton Railway Company, to proceed to South America to negotiate a contract for the Cordova and Tucuman Railway, and a few years later he was engaged on behalf of Messrs. Erlanger and Co. to examine the property and report on a proposal to purchase the undertaking of the Alabama and Chattanooga Railway in the United States. The result of the last investigation was the formation in 1877 of the Alabama Great Southern Railway Company, of which Mr. Jacomb-Hood was a Director until 1886. On a subsequent occasion, in 1879, he was again commissioned by Messrs. Erlanger to investigate the affairs of other undertakings in the West Indies and in the Southern States of America. Subsequently to 1880 he acted as a Director of several undertakings, including the Thames Haven Petroleum Storage Company, the New Gas Company, the Sydney and Louisburg Railway and Coal Company, and the Assam Railways and Trading Company, in the business of all of which he displayed that honesty of purpose and practical ability which distinguished him throughout his career.

In March, 1883, on the retirement of Sir Arthur Otway, Mr. Jacomb-Hood was invited to accept a seat on the board of the London, Brighton, and South Coast Railway Company, and in this way he renewed the close connection with which his earlier years were associated. For the last seventeen years of his life he devoted almost all his energies to the business of the London, Brighton, and South Coast Railway Company. His whole interests were centred in the Company's affairs, and he spared no pains to place at their service that keen intellect, fine memory and tactful discrimination for which he will be long remembered. In almost full vigour of health he died suddenly at Tunbridge Wells, on the 10th May, 1900, in the 79th year of his age, having been engaged on the day of his death in transacting business for the Brighton Company.

Mr. Jacomb-Hood was one of the oldest Members of the Institution, having been elected to that class on the 2nd March, 1847.

HENRY LAW was born at Reading on the 15th April, 1824. At an early age he was sent to school at Hackney, but trouble with his eyes necessitated his leaving school when only 8 years old. Three separate operations for cataract were performed, but the sight of one eye was never recovered. At 10 years of age he went to school again, remaining there until he was 13, and during that time he made several mechanical models and drawings. These were brought to the notice of Sir Isambard Brunel, who took Henry Law into his office for two months, and subsequently gave him articles as a pupil. He was then placed on the Thames Tunnel staff, and remained on those works until their completion in 1843.

He was next employed by Mr. Thomas Page, who had been chief of the Thames Tunnel engineering staff, to assist in taking soundings and in making surveys of the River Thames. In 1844 Mr. Page became Engineer to the Commissioners of Woods and Forests, and Mr. Law entered his office as an Assistant. In that capacity Mr. Law assisted in the design and survey of several works connected with the Thames, and acted as Resident Engineer for the Windsor Improvements, including the Victoria and Albert Bridges, finally leaving Mr. Page in 1850.

In 1852 Mr. Law began to practise on his own account, and in 1853 was joined in partnership by Mr. John Blount. He erected three bridges over the River Wye, and also spent some time in Portugal with Mr. Thomas Rumball, making surveys for the Central Peninsular Railway. In 1855 he went to Rio de Janeiro to report on a proposal to construct a slip at Bahia. This brought other work, and he remained in Brazil until 1863, carrying out a number of important works there, among which may be mentioned the Ilha das Cobras Dock, Bahia Gasworks, Ceara Gasworks, and Pernambuco Drainage. He returned to England in 1865, but made several visits to Brazil until 1875, when he once more settled down to practise in England.

In 1878 he entered into partnership with Mr. George Chatterton and the connection lasted until 1887. Mr. Law, as senior partner in the firm of Law and Chatterton, enjoyed a large practice as a consulting engineer, and was employed by the late Metropolitan Board of Works to act in conjunction with their Engineer, the late Sir Joseph Bazalgette, on most of their Parliamentary Bills. He was engaged in the long series of inquiries which finally resulted in the freeing from toll of all the Metropolitan bridges. He was also engaged on the Thames Flood Prevention Bills, and

in both the protracted inquiries dealing with the discharge of the London sewage into the Thames at Barking and at Crossness. After the Tay Bridge disaster he was instructed by the Government to report fully on the cause of the accident, and in 1892 he was appointed by the Foreign Office to consider, with German and French colleagues, the various schemes for the drainage of Cairo submitted to the Egyptian Government.

During Mr. Law's long and varied career he was associated with many works in various parts of England, but for some years past he was more intimately concerned with works of sanitation, his latest being the drainage of Oldham and Broadstairs, and the prevention of flooding at Eastbourne. Mr. Law possessed mathematical powers of a high order, and his calculations were most refined and accurate. He was of a very inventive turn of mind, and devised for his own use, among other things, an electrical sounding apparatus and an electrical current meter. He was the author of several mathematical and engineering books, among which may be mentioned, "Examples of the Modes of Setting-out Railway Curves," "Mathematical Tables for Trigonometrical, Astronomical, and Nautical Calculations," "The Rudiments of Civil Engineering," and "The Art of Constructing Common Roads." Mr. Law took great interest in the Sanitary Institute, of which he was for many years a Member of Council, and at the time of his death Chairman of Council.

Mr. Law died at his residence in London on the 18th July, 1900, having just attained his 76th year.

He was elected a Member of the Institution on the 5th February, 1867.

WILLIAM LINDLEY died at his residence, 74 Shooter's Hill Road, Blackheath, on the 22nd May, 1900, in his 92nd year. Born in London on the 7th September, 1808, he was the younger son of Mr. Joseph Lindley, of Heath in Yorkshire, some time Assistant to the Astronomer Royal at Greenwich Observatory. When only three months old he lost his father. He was educated at Croydon, but feeling the want of stricter discipline than that afforded at home, at the age of sixteen he obtained permission from his mother to continue his studies at Wandsbeck, near Hamburg, in the house of Pastor Schroeder. On returning to England he entered, in June 1827, the office of Mr. Francis Giles as a pupil, and subsequently assisted that engineer in design-

ing the Newcastle and Carlisle Railway, now part of the North Eastern Company's system, and the London and Southampton Railway. On the latter he was entrusted with the construction of the bridges. He left the service of the London and Southampton Railway Company in 1836. During that period he had also been employed on the regulation of the River Mersey, and for a time on the works of Brunel's Thames Tunnel.

In 1837 and 1838 Mr. Lindley was engaged on railway work in Germany and Italy, and on the formation of the Hamburg-Bergedorf Railway Company he was appointed Engineer-in-Chief. Acting under the instructions of the Hamburg Government he worked out the designs for connecting that line with the great trunk-line extending to Berlin. Immediately after leaving Hamburg it passed through the "Hammerbrook," a low marshy district, which from its position in immediate proximity to the city would in all other respects have formed a most natural site for the extension. It was, however, considered to be an "unimprovable swamp," and Mr. Lindley's suggestion to lay out a systematic network of streets and canals, embracing the whole district, and thus to transform it into valuable building ground for warehouses, factories, etc., was met with opposition and even ridicule from all but a few. His proposals, made in 1840, were, however, adopted, and were carried out under his direction. An area of about 1,432 acres was successfully drained, a portion of which has become a very important part of the city of Hamburg.

In 1841 Mr. Lindley designed the long railway carriages with six wheels, which were used for the first time on the Hamburg-Bergedorf line, and afterwards became more or less typical for other continental lines. About this time, too, he was entrusted with negotiations on the part of the State of Hamburg with the British Government for introducing a cheaper rate of postage between London and Hamburg, his desire being to see established a universal rate of 2*d*.

The Hamburg-Bergedorf Railway was to have been publicly opened on the 7th May, 1842. The great fire of Hamburg, which lasted three days and nights and destroyed a considerable part of the town, broke out at 1 A.M. on the 5th of that month, and Mr. Lindley proposed energetic measures to cut off the further progress of the fire by blowing up a line of buildings in its course. Being entrusted with the direction of the operations, he at once proceeded to blow up the Town Hall, and after unremitting activity during three days and two nights, succeeded in retarding the conflagration and in limiting its

area. His life was in great danger, not only imperilled by the work itself, but by rumours which had found credence with the ignorant classes, that the English meditated blowing up and destroying the Port of Hamburg and that he was acting as chief agent of the plot. The city authorities were obliged to take strong measures to protect the lives of Mr. Lindley and his English assistants and, after the extinction of the fire, the Senate found it necessary to contradict officially the absurd rumour, and it publicly thanked Mr. Lindley for his great services. The first use made of the newly-opened railway was to transport the homeless poor out of the burning city.

It was this great fire which opened a wide field to Mr. Lindley's talent and led him to develop that line of municipal engineering, and especially sewerage and water-supply, with which his name subsequently became identified. While the ruins were still smouldering, he received instructions from the Senate to design the rebuilding of the city. The special committee of the Senate and Town Council nominated in consequence of the fire, appointed him Consulting Engineer, and he likewise became Consulting Engineer to the Hamburg Water Board and to the Board of Works, holding those offices till the close of 1860. He thus designed and carried out most of the great public works which marked the transformation of the town of Hamburg into an important modern city. Prominent among these are, besides the above-mentioned Hammerbrook works, the sewerage of the city, the water-supply, and the extension of the Hamburg-Berlin Railway terminus and goods station.

The sewerage works were commenced immediately after the fire, and in 1860 the network of sewers had an extent of 40 English miles. The chief characteristic of the Hamburg drainage works was the completeness of the system, as the plan was not hampered by having to embody existing sewers, and the whole network could be designed as best suited to local conditions. It was divided into an upper and a lower system: the upper system independent of the floods in the river for its outfall, and the lower system limited to the low-lying tracts, with artificial means of keeping down the water-level in the sewers during high water in the river. The sewers were laid at a considerable depth, so as to drain the subsoil and the cellars; the system was from the commencement based on the universal use of the water-closet and on carrying off all sewage in a fresh condition, catch-pits in the sewers themselves being avoided. Curves of large radius and tangential junctions were used to facilitate the flow. A complete system of artificial flushing

was adopted; all branch sewers were so connected at their upper ends as to permit flushing them from the next line of intercepting sewer; and a thorough system of ventilation was carried out for both street sewers and house drains.

These principles were to a great extent novel at the time (1842) and Mr. Lindley's proposals were severely criticised by many and pronounced to be irrational and certain to lead to failure. The Hamburg literature of that time is most interesting on these points and proves how hotly the controversy was carried on by both sides.

In conjunction with Mr. W. C. Mylne, at that time the Engineer to the New River Water Company, Mr. Lindley, in February 1844, reported on works for the water-supply of the city of Hamburg. They were carried out from 1844 to 1848 under his direction and from his designs, as were likewise the extensions of the same until the end of the year 1860, the date of his leaving Hamburg. The water was taken from the Elbe at Rothenburgsort and clarified by means of subsidence-tanks before being pumped into the town. Provision was made to raise the pressure at night in order to supply some of the higher districts and to obtain increased pressure in case of fire. This design was likewise untrammelled by previous works and could be drawn up and carried out purely with regard to the best solution for local circumstances. It was the first comprehensive and systematic water-supply on modern principles on the Continent. A characteristic feature was the careful design and disposal of the works, and especially the network of piping, with regard to their systematic extension to meet the demands of the far future. A further feature, resulting from the influence of the great fire, was the ample provision made for fire-extinguishing purposes by means of large hydrants. But above all it should be mentioned that these works formed one of the first large water-supplies carried out by a corporation for the supply of its city, and with the express object of delivering water at a very cheap rate and under exceptionally favourable circumstances to the poorer classes. In 1853 Mr. Lindley designed large extensions of the works, and sand filters to supplement the method of clarification by subsidence which had become inadequate. These works were, however, only partly carried out; the execution of the filters was unfortunately delayed and became the subject of a controversy which lasted over 30 years, and was in fact only brought to a conclusion by the construction of sand-filters at the time of the disastrous outbreak of cholera in 1892–93.

In 1860, when Mr. Lindley left Hamburg, about 11,000 houses

were supplied with a maximum quantity of 7 million cubic feet of water per week.

After the great fire Mr. Lindley proposed a complete trigonometrical survey of the city and its suburbs, and he was entrusted from 1848 to 1860 with the direction of the work.

The Gas Company in 1846 called in Mr. Lindley to design and carry out the Hamburg Gas Works on the "Grasbrook." On the basis of his design, which allowed for future extensions of these great works, he carried out the first part of the same. Their characteristic features were the magnitude of the design and the systematic disposition of the factory to minimize the cost of labour and transport.

In 1851 he suggested the erection of large public baths and wash-houses at Hamburg for the poor. This model establishment was carried out according to his plans on the Schweinemarkt by voluntary subscription and inaugurated in 1854. In the same year various extensions to the Port of Hamburg were carried out by him, based on the designs prepared by Messrs. Walker, Huebbe and himself in 1845. In 1850 he was instructed by the three cities of the Hansa—Hamburg, Bremen and Luebeck—to negotiate the sale of their "Steelyard," a large wharf on the banks of the Thames. The sale was effected two years later, and Cannon Street Railway Station now stands on that site.

In February 1851 Mr. Lindley was called in by the Directors of the New River Company, London, to report on the adoption of the system of constant supply, and his proposals formed the basis of large works of extension carried out at Stoke Newington, Green Lanes, and in the district supplied by the Company.

In the same year the British Government entrusted him with various works on the island of Heligoland, including the construction of the great retaining wall "am Falm."

In 1855 Mr. Lindley supervised for the municipality of Hamburg the carrying out of the Altona Gas and Water-works, the latter of which had been designed for the owners of the undertaking by Mr. Thomas Hawksley, Past-President. The water-works draw their supply from the River Elbe, about 7 miles below Altona; it is there lifted 280 feet to an elevated plateau, filtered and stored in covered reservoirs, and thence carried to Altona in cast-iron mains. This was the second water-works on the Continent, Berlin being the first, in which sand filtration was adopted. During his residence in Hamburg Mr. Lindley was consulted and employed on numerous other extensive designs, among others the Berlin, Kiel, Stralsund, Stettin and Leipzig Water-works, and he took part in preparing

plans for bridging the River Elbe to connect the network of railways north of the river at Hamburg with those on the south at Harburg.

At the close of the year 1860, in consequence of the serious illness of his wife, whom he lost in 1862, he left Hamburg and took his family to the south of France, and thence to England.

In 1863 Mr. Lindley was invited by the authorities of Frankfurt-am-Main to report, with other experts, on the drainage of that city, and in 1865 he was appointed Consulting Engineer to the city. The sewerage works were carried out according to his designs and under his direction, his Resident Engineer till the year 1873 being the late Mr. Joseph Gordon, and till the end of 1879, the year of his retirement, his eldest son, Mr. W. H. Lindley. The Frankfurt sewerage works are characterized by a still more accentuated carrying out of the principles adopted in Hamburg; and further by the adoption of the egg-shape sewer, by the extensive use of the 2-foot by 3-foot brickwork sewer which forms about 50 per cent. of the whole network, by the great extent to which tunnelling was made use of in the narrow streets of the older parts of the town, and by the first adoption of the deep stoneware street-gully known as the "Frankfurt gully." Ventilating shafts were built where the upland sewers ended on the high lands surrounding the city, the towers of the old fortifications being in some cases utilized for this purpose, and reservoirs were constructed to collect flushing water at the top ends of the various systems. These were rendered necessary as there was not an efficient water-supply till six or seven years after the sewer works had been commenced. Great care and attention were paid to house-drainage and stringent by-laws and model plans were for the first time worked out and published. When Mr. Lindley left Frankfurt in 1879, there were about 80 miles of street sewers, serving about 15,000 dwellings, with some 19,000 water-closets.

During the execution of these works, Mr. Lindley proposed a survey of the city similar to that of Hamburg, and it was carried out under his direction by the City Surveyor, Mr Spindler. Mr. Lindley was consulted by the city authorities as to the remodelling of the railway system, and advocated the construction of a large Central Station on the site of the present well-known fine building.

In 1868 Mr. Lindley was called in by the city of Pest to report on the water-supply. He indicated a comprehensive design for the supply, but as the necessary funds were wanting, only a part was executed. Before the end of the year these works were opened and with the revenue they gave further sums were raised

and the works extended. He was also consulted on water-supply questions by Düsseldorf, Chemnitz, Basel, Galatz, Braila and Jassy, and on sewerage questions by Düsseldorf, Basel and Crefeld. His last professional work was the general design for the sewerage and waterworks of the city of Warsaw, and for the sewerage works of St. Petersburg, in the years 1878–79. The latter have not yet been constructed, but the Warsaw sewerage and water-works were carried out under the direction of his sons, William, Robert and Joseph, whom he left to continue his work on his retirement at the end of 1879.

The greatest works of Mr. Lindley are those at Hamburg, more especially the Hamburg and the Hammerbrook drainage, and the sewerage of Frankfurt-am-Main. The so-called Hamburg-Frankfurt system has become more or less typical for sewerage works in Germany and Austria, while the drainage of many large cities in America has been modelled after the Frankfurt works. The chief characteristics of Mr. Lindley's works were the thoroughness and far-sightedness of his designs which were always based on the demands of a far future, the care spent on details of construction, and their conscientious execution, his great resource and inventive genius ever finding practical solutions for difficult questions. His simple, straightforward thoroughness of purpose, his indefatigable energy, and his kind genial nature always won and retained the confidence of those who sought his advice, and the willingness and devotion of his assistants. He was a true friend to his workmen, and one of his main objects and greatest pleasures in life was to further the well-being of others. His reports bear witness to the conscientious and painstaking manner in which he tried to place a subject clearly in all its salient points before the authorities who had to decide upon it, and he had a peculiar way of making technical questions, even when of an intricate nature, clear to those with whom he had to deal, and of convincing them of the correctness of the views he advanced. One of his marked traits was a constant good humour, which carried him through many a difficult situation. He had a wonderful intuitive knowledge and judgment of men. He was not only an engineer, and did not limit himself to the technical side of the questions submitted to him, but generalised and looked at them from all points of view; and in fact the success of many of his works was due to his clear judgment and advice on the financial side of the subject.

After his retirement from active life in 1879, Mr. Lindley devoted his time to travel and reading. He had been a Fellow of the Geological Society from 1841, and from 1844 a Member of

the Smeatonian Society of Engineers, of which body he acted as President in 1864. He was the recipient of many interesting letters of recognition for services rendered, among others from the authorities of the City of Hamburg after the great fire, and again in 1892 on the occasion of the fiftieth anniversary of that fire; and at the news of his death the cities of Hamburg and Frankfurt-am-Main sent last messages of grateful acknowledgement of the services he had rendered them. How long he outlived his contemporaries is evidenced by the fact that he enjoyed the personal friendship of Cobden, John Stuart Mill, Professor Fawcett, Sir Rowland Hill, Professor Wheatstone, Sir Charles Lyell, Justus von Liebig, Sir George Gilbert Scott, Joseph Prestwich, Edwin Chadwick, Sir John Hawkshaw, Sir Joseph Whitworth, William Chadwell Mylne, John Frederic Bateman, Thomas Hawksley and Sir Robert Rawlinson.

Mr. Lindley was one of the oldest Members of the Institution, having been elected on the 1st February, 1842.

THOMAS DAVID LITTLE was born at Reading on the 19th December, 1842, and was educated at Caversham House Academy. After serving articles to the late Mr. J. B. Clacy, County Surveyor for Berkshire, he was engaged for about eighteen months in the Engineering Department of the Great Western Railway.

In 1861, as the result of competitive examination, Mr. Little was appointed an Assistant Engineer in the Bombay Public Works Department. After being stationed successively at Poona, Ahmedabad, Surat and Panch Mahals, he was posted to Kaira in 1869 and placed in charge, as Executive Engineer, of that large district, in which, during the following eighteen years, he designed and carried out many important works, including upwards of 150 miles of metalled roads, numerous tanks and other irrigation works, and a large number of masonry and iron bridges, besides being instrumental in securing the construction of branch railways. In 1887 he was transferred to Khandesh, and in 1889 was promoted to the rank of Superintending Engineer, 1st class. From December, 1889, to May, 1890, and again from 1894 till his retirement in December, 1896, he served as an Additional Member of the Council of the Government of Bombay for making Laws and Regulations. Mr. Little was promoted to be Chief Engineer of the Bombay Presidency in

1891, and in 1894 became Secretary to the Government of Bombay in the Public Works Department. In the following year he was appointed a Companion of the Order of the Indian Empire.

Throughout his long career in Bombay Mr. Little's services were notably able and devoted, his judgment was always sound, and was sought by his colleagues and by the Government in many matters beyond the scope of the profession. His conspicuous services in the organization and administration of the great famine-relief works which became necessary during the last year of his service in Bombay were the subject of appreciative official notice, and he crowned a distinguished career by volunteering—in 1897 and again later—his services, without salary, for the campaign against plague and famine in which the Presidency was engaged.

On his retirement from Government service Mr. Little returned to England, where he died suddenly on the 16th May, 1900, at Chester.

Mr. Little was elected a Member of the Institution on the 5th May, 1885.

ANDREW MORTON, born on the 2nd June, 1847, began his engineering career as a pupil of Mr. George Leedham Fuller. After obtaining some practical experience at the Avonside Engine Works, Bristol, and in the works of Messrs. Westwood, Baillie and Company at Poplar, he passed in 1869 the competitive examination for the Indian Public Works Department, and in November of that year was appointed by the Secretary of State for India an Assistant Engineer, 3rd grade. For some years he served as an Assistant Engineer on irrigation and military works in the Punjab and in the North Western Provinces. In September, 1878, he was transferred to the Central System of State Railways and posted to the Holkar and Neemuch line, on which he remained until March, 1879, when he was drafted to the Western Rajputana State Railway. After acting for a time as Locomotive Superintendent of that line, he was appointed District Locomotive Superintendent in May, 1881.

In April, 1882, Mr. Morton was transferred to the Nizam's Guaranteed State Railway as District Locomotive Superintendent. During the latter part of 1883 and the beginning of 1884 he acted as Manager and Traffic Superintendent of the line, and was personally thanked by the Viceroy of India for the excellent arrangements made to meet the heavy traffic at the time of the

installation of the Nizam. In June, 1885, he was transferred to the Northern Bengal State Railway as Locomotive Superintendent, and in September, 1888, he was drafted to the Tirhoot State Railway in a similar capacity On that line he remained only six months, being posted in April, 1889, to the North Western Railway as District Locomotive Superintendent. He was promoted to Deputy Locomotive Superintendent in 1890, and in August, 1893, he was transferred to the East Coast State Railway as Locomotive Superintendent. That post he held until his death, which took place at Waltair on the 3rd June, 1899.

Mr. Morton was of a somewhat retiring disposition, and not very well known outside the limits of his professional work. In social life he was reserved and self-contained. Of massive frame, he was looked upon with awe by his native subordinates. He was a conscientious and able officer in the Locomotive Department, and was greatly respected by all who knew him and his real worth.

Mr. Morton was elected a Member of the Institution on the 7th February, 1893.

RICHARD PROCTOR-SIMS died on the 31st May, 1900, at Port Albert Victor, in the Bhavnagar State of Kathiawar in Western India. He began his professional career as an Assistant Engineer on the staff of the Bombay Municipality, which post he resigned in 1864 to join the engineering staff of the Back Bay Reclamation Company. On the termination of this Company's work, he was appointed in December, 1869, Executive Engineer for Local Funds in the Nassick districts, and later, on the abolition of the Local Fund Department, he was transferred to Government service as 4th grade Executive Engineer in the Bombay Public Works Department.

In the year 1875, at the request of the Administrators of the Bhavnagar State, Mr. Proctor-Sims' services were lent as State Engineer, and for the following twenty-five years till the date of his death he devoted himself not only to the engineering, but also to the general welfare of the State of Bhavnagar. One of his first cares was the organization of the State Public Works Department and the introduction of a Public Works code and system of accounts. In addition to the ordinary routine work of a State Engineer, which included the construction of 130 miles of roads with their necessary bridges, and the water-supply and sanitation of Bhavnagar City, the following notable buildings were either designed or carried

out by Mr. Proctor-Sims:—the High School, the High Court, the Anglo-Vernacular School, the Nilambag Palace, the Samaldas College, and the Takhtsingji Hospital, the last named being designed by Mr. William Emerson. Mr. Proctor-Sims devoted much attention to the harbour works of the State. Having done much to improve the Port of Bhavnagar, he was interesting himself in developing the new Port Albert Victor, and it was during the famine in May, 1900, while organizing relief works at this Port that he fell a victim to cholera which was raging in the district.

As the most trusted European official in the State Mr. Proctor-Sims was constantly consulted by the Maharajah on important measures other than those connected with engineering. The horse-breeding operations of the State and the Bhavnagar Imperial Lancers were practically organized by him; and indeed every matter of importance in the State, including its relations with the Imperial Government, was carried out either by him or under his guidance. Perhaps the department in which his work was most important was that of the Board of Control of the Kathiawar system of State Railways, in which the Bhavnagar State has a large interest.

Mr. Proctor-Sims was a man of great unselfishness, his hospitality was proverbial, and his genial social qualities made him liked everywhere. His untimely death was keenly felt, not only by the Maharajah, but by the people of the State generally, by whom he was universally trusted and respected.

Mr. Proctor-Sims was elected an Associate of the Institution on the 5th May, 1868, and was transferred to the class of Members on the 9th May, 1876.

JOHN BALDRY REDMAN, who died at Virginia Water on the 21st December, 1899, was for some time before his decease the "Father of the Institution," having been elected a Graduate on the 26th February, 1839, from which class he was transferred to that of Members on the 3rd March, 1846. Thus his connection with the Institution lasted upwards of 60 years.

Born in 1816, he outlived nearly all his contemporaries, and considerable difficulty has been experienced in preparing this notice. His engineering training was obtained in the office of Messrs. Walker and Burges, which he entered as a pupil about the year 1834. While with them he was employed on various works on the

Thames, and it was thus that he laid the foundation of that extensive knowledge of the river which characterized him in later life. He used to relate how, as a lad of eighteen, he was deputed, in the absence of Mr. Walker from illness, to show a large party—the Duke of Wellington and Sir Robert Peel among them—over the graving dock of the Surrey Commercial Docks, his senior fellow pupil having disappeared in sheer fright when informed of the unexpected arrival of the party. Young Redman was afterwards thanked by Sir Robert Peel for the clearness of his explanations. While still a pupil he contributed in 1839 the first of many Papers to the Institution, "An Account of the New Stone Bridge over the River Lea at Stratford-le-Bow,[1] for which Mr. Walker was Engineer. For that communication he was awarded a Telford medal in bronze and books to the value of three guineas. After the expiration of his pupilage he remained with Messrs. Walker and Burges as an Assistant until 1841, when he started on his own account, taking an office in Great George Street, Westminster. From that year until 1885 he occupied various offices in Westminster, his practice, however, declining somewhat with advancing age.

His second Paper, contributed to the Institution in 1842, was a "Description of the Maplin Sand Lighthouse at the Mouth of the River Thames," [2] on the construction of which he had been engaged under Mr. Walker, who, it will be remembered, was for some years Engineer to the Trinity House. In 1845 he presented an "Account of the New Cast-iron Pier, at Milton-on-Thames, next Gravesend, in the County of Kent; with details of the mode of construction adopted in its erection." [3] This work, known as the "Royal Terrace Pier," was designed by him and carried out under his superintendence by Messrs. Fox, Henderson & Co., of the London Works, Birmingham. In 1848 appeared a fourth Paper from his pen entitled "Remarks on the Formation of Entrances to Wet and Dry Docks, situated upon a Tideway; illustrated by the principal examples in the Port of London," [4] for which he was awarded a Telford Premium.

Mr. Redman's careful investigation of London dock entrances was followed by an exhaustive study of the South Coast, the outcome of which, in 1852, was a Paper "On the Alluvial Formations

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[1] Transactions Inst. C.E., vol. iii. p. 343, and Minutes of Proceedings Inst. C.E., vol. i. (1839), p. 77.

[2] Minutes of Proceedings Inst. C.E., vol. ii. (1842) p. 150, and vol. vii. p. 146.

[3] *Ibid*, vol. iv. pp. 77 and 222.

[4] *Ibid*, vol. vii. p. 159.

and the Local Changes of the South Coast of England." [1] For this communication, which gave rise to an animated discussion, he was awarded a Council Premium of books. In 1855 he constructed a large wharf and tidal docks at East Greenwich, and executed the repairs of the pier at West Greenwich.[2] The Paper on the South Coast was followed in 1864 by "The East Coast between the Thames and the Wash Estuaries," [3] for which he obtained a Telford Premium. The object of these valuable communications was to describe the characteristics of ranges of coast within certain limits, to trace the changes produced by constant natural causes, and the resultant influences on various harbours.

In 1877 appeared Mr. Redman's seventh and last Paper, "The River Thames," [4] for which he again obtained a Telford Premium. So far back as 1856 he had contributed, in the course of the discussion on a Paper on the same subject by Mr. Henry Robinson, an historical notice [5] of the river which was the embodiment of upwards of twenty years' experience and study of that important waterway. His communication of 1877, the result of more than forty years' work, comprised a great deal of valuable information, historical and statistical, with regard to the Thames, tracing the causes which had led to the improvement in its navigable channel, and furnishing data as to the comparative action of the tides in the river for eighty years. While setting forth that modern improvements had added, during nearly half a century, about 33 per cent. to the above-bridge tidal volume operating twice every twenty-four hours, he pointed out that the evils arising from the non-embankment of the low-lying portions of the metropolis would be intensified year by year with the development of the tidal improvements until met by some well-considered and comprehensive measure.

In addition to these Papers, Mr. Redman frequently took part in discussions on subjects ranging from rivers, coasts, docks, and harbours, to tramways, railways, and street pavements; indeed, reference can scarcely be made to one of the first seventy volumes of the Proceedings without finding some contribution from his store of knowledge and experience, or some evidence of original thought. For many years before giving up his office in Westminster he was a daily frequenter of the Reading Room of the Institution, and his

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[1] Minutes of Proceedings Inst. C.E., vol. xi. p. 162.
[2] *Ibid*, vol. xv. p. 216.
[3] *Ibid*, vol. xxiii. p. 186.
[4] *Ibid*, vol. xlix. p. 67.
[5] *Ibid*, vol. xv. p. 211.

short, compactly-built figure and keen, intelligent features were well known there. Of a somewhat masterful and self-assertive disposition, he was, nevertheless, kind and genial to those able to penetrate the hard crust of his outer man.

During the latter years of his life he held the post of District Surveyor for North-east Deptford, to which he was appointed by the late Metropolitan Board of Works on the recommendation of his old friend and fellow pupil, Sir Joseph Bazalgette. He was confirmed in this office when the London County Council was formed, and, in order to be able better to perform his duties, resided in the New Cross Road. Full of energy to the last, he worked until within a month or two of his death, in order that he might meet some fancied obligations which would never have been advanced against him.

Professor CALLCOTT REILLY, who from 1871 to 1897 held the important chair of Engineering Construction at the Royal Indian Engineering College, Coopers Hill, died at the Clergy House, Englefield Green, on the 21st May, 1900.

Born in 1829, his early life was one of adventure. When still a lad, bitten by a longing for the sea, he ran away from Chester, made his way to the Liverpool Docks, and was about to sail on board a small coasting-vessel as cabin boy when he was found by his father and brought home again. About a year later he ran away a second time, and was again found on a ship in the Liverpool Docks by his father, who this time did not bring him back, but bound him apprentice to a shipowner. He made two voyages to the East Indies and one to North America on a timber ship, but, although he always strove to be first in the performance of duty, the hard life of an ordinary seaman in the merchant service of that day cured him of his longing for the sea, and, as soon as he could get free, he turned his attention to engineering, and became an apprentice of Messrs. Edward and Bryan Johnson, millwrights, of Chester.

After the expiration of his engineering apprenticeship, Callcott Reilly was for two years (1852–54) foreman of pattern-makers at the works of Messrs. Knight and Woods, of Bolton, and was subsequently for twelve months chief foreman at the works of Mr. Joseph Clayton, millwright and engineer, of Preston. His next employment was as draughtsman in the office of Mr. James Hodgson, of Liverpool, one of the pioneers of iron-shipbuilding.

There he remained until 1857, when he came to London and entered the service of Mr. Edward Woods, Past-President, as Principal Assistant in charge of office work.

During the fourteen years Callcott Reilly was with Mr. Edward Woods he was engaged on investigations and designs demanding high proficiency in the science and practice of engineering construction. Every spare moment he devoted to the study of mechanics and the higher mathematics. After the day's work at the office he would reach his chambers in King's Bench Walk, Temple, about 6 o'clock, and, first dining, would go to bed, getting up about midnight when all was quiet and working until 5 in the morning, when he would take out the remainder of his sleep. It was thus by dauntless energy and sheer hard work that the man, who had begun life as an apprentice in the merchant service, gradually made himself a name as a designer of bridges and as a practical engineer imbued with scientific principles.

As a result of his investigations Callcott Reilly presented to the Institution in 1865 a careful and elaborate Paper entitled "On Uniform Stress in Girder Work, illustrated by reference to two Bridges recently built."[1] The bridges in question were that carrying the line of the Central Argentine Railway over the River Desmochado, or Carcarañal, about 30 miles west of the town of Rosario, and the Horsham and Guildford Railway Bridge over the Wey and Arun Canal, about 5 miles south of Guildford. The conclusions he sought to establish were that a comparatively small deviation of the centre of stress upon the cross section of any bar, of any piece of framework, from the centre of gravity of that section, produced, within the limits of elasticity, a comparatively great inequality in the distribution of the stress upon that section; that the existence of this unequal distribution of the stress must be detrimental to the strength of any structure in which it existed; that there was no practical or theoretical difficulty in designing a truss, or girder, in which the stress upon every cross section—of all the important members at all events—should be absolutely uniform; and that the condition of uniform stress was perfectly consistent with the utmost economy of material.[2] For this Paper, which combined elaborate theoretical investigation with good practical results, the Author was awarded a Telford medal and premium.

In 1870 Callcott Reilly submitted a second Paper, entitled

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[1] Minutes of Proceedings Inst. C.E., vol. xxiv. p. 391.

[2] *Ibid*, vol. xxiv. p. 422.

"Studies of Iron Girder Bridges, recently executed, illustrating some Applications of the Modern Theory of the Elastic Resistance of Materials."[1] In this communication he sought to bring to the notice of engineers systems of construction embodying an attempt at accurate conformity to scientific principles, with practical efficiency and economy. His aim also was to afford to students some examples—of very different types—of systematic computation and minute study of proportion, illustrating the modern theory of the elastic resistance of materials and the practical application of some of the simpler branches of that theory in a way which it was hoped might be useful.

He took a very prominent part in the movement which led to the establishment, by the Institution, of the Student class in 1867, and continued throughout his life to promote in every way the interest of that class. He also proposed the systematic inquiry into the state of the professional education of engineers on the Continent and in the United States, the result of which was the publication by the Institution in 1870 of the pamphlet entitled, "The Education and Status of Civil Engineers in the United Kingdom and in foreign countries."

Callcott Reilly's name and work were now well known in the engineering world, and in 1871 he was selected by the late Sir George Chesney for the specially important professorship of Engineering Construction in the Royal Indian Engineering College, then being established at Coopers Hill for the education of candidates for the service of the Government of India in the Department of Public Works. Very diffident as to accepting this appointment, demanding not only knowledge, but the power of imparting knowledge to others, as to which he was wholly inexperienced, he decided finally to put the matter before his friend, Professor Rankine, who expressed the opinion that he was "the very man for the post." This opinion was fully justified. Sir George Chesney's selection proved most happy and satisfactory, and Professor Reilly discharged the duties of the post for a period of twenty-six years. He brought to the work a firm determination to succeed in the duties he had undertaken, and he succeeded. Perhaps his most valuable quality was that as to which he had been most diffident—a marked power of making the way plain to students, and of leading them forward step by step in such a manner as to free the problem from many of its difficulties. No amount of trouble was too great for him; he devoted himself

[1] Minutes of Proceedings Inst. C.E., vol. xxix. p. 403.

without stint to the interests of the College; his house was the centre of hospitality and of kindness; and he was popular with all, as such a man could not fail to be. A marked characteristic was his love of books, his "friends" as he often called them, and he brought together a library, by no means restricted to engineering works, and containing many rare editions and choice bindings. In his retirement he devoted himself to general literature, Norse legends and sagas having special charm for him, for he had a romantic side to his character and loved poetry and romance. A few months before his death he met with a severe tricycle accident, being badly cut and bruised by a fall caused by an effort to save a child from danger. The injury thus sustained and the anxiety caused by the illness of one of his sons, were largely instrumental in causing his death.

Callcott Reilly was elected an Associate of the Institution on the 6th December, 1864, and was transferred to the class of Members on the 10th May, 1870.

ROBERT ANDREW ROBERTSON was born in Islington on the 23rd April, 1843. After serving his apprenticeship with Messrs. James Simpson & Co., of Pimlico, he went in 1864 to Lichfield, where, as Assistant to the late Mr. David Thomson, he carried out some extensive tunnelling operations for the South Staffordshire Waterworks. From 1866 to 1872 he was Manager, for Mr. James Duncan, of the Clyde Wharf Sugar Refinery, where he laid the foundation of the extensive and intimate knowledge of the handling of sugar for which he was well known in later years. In 1872 he went to Glasgow, and ultimately became a partner in the firm of Mirrlees Watson & Co., a name known in all sugar producing countries, most of which Mr. Robertson visited in the course of business. His private correspondence was extensive and his advice much sought, but his great modesty of character prevented him from seeking the public recognition which his capacities and labour might have obtained. He died suddenly of apoplexy on the 2nd June, 1900, while on a voyage to the Argentine Republic, and was buried in the English cemetery at Corunna.

Mr. Robertson was elected an Associate of the Institution on the 2nd March, 1869, and was transferred to the class of Members on the 14th May, 1878.

RICHARD BARNSLEY SANDERS, born on the 6th October, 1845, was educated at Queen's College, Belfast, and obtained in 1866 the diploma in Civil Engineering, with honours, of Queen's University, Ireland, the degree of Bachelor of Engineering being conferred voluntarily upon him by the Royal University of Ireland in 1878. He served a pupilage to the late Mr. James Thomson, afterwards Professor of Civil Engineering at Glasgow University; and was then engaged, first as an Assistant, and subsequently as Contractor's Engineer, on the construction of the Downpatrick, Dundrum and Newcastle Railway, in 1868–69. After acting as an Assistant on the construction of the Belfast Central Railway from 1870 to 1872, and being employed in 1873 on plans for Belfast Waterworks, he obtained in 1874, by competitive examination, the appointment of County Surveyor of King's County. That post he held until his death, which took place at Parsonstown on the 13th February, 1900.

Mr. Sanders was also engaged in private practice, and designed and carried out engineering works of varied character. He was a Member of the Institution of Civil Engineers of Ireland, of the Incorporated Association of Municipal and County Engineers, and of the Royal Dublin Society. To this Institution, of which he was elected a Member on the 2nd February, 1897, he contributed a Paper entitled "The Management, Maintenance and Cost of Public County Roads in Ireland under the Irish Grand Jury System."[1]

HAMILTON SMITH, who died suddenly of heart disease at his residence in Durham, New Hampshire, U.S.A., on the 4th July, 1900, was born at Louisville, Kentucky, on the 5th July, 1840. In order to gain a knowledge of engineering he was employed at an early age—from 1854 to 1859—under his father, who was at that time the technical manager of the Cannelton Coal Mines in Indiana, on the Ohio River. He gave immediate evidence of ability, and rose rapidly to be chief of the engineering and accountant's departments. From 1859 to 1867 he was engaged in Indiana and Kentucky in developing important collieries and in superintending the construction of the necessary railroads and machinery. In 1869 he was appointed Engineer and Manager of

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxv. p. 258.

the North Bloomfield Gravel and Milton Mines in Nevada County, California, where he designed and carried out large and important works, and became the recognised authority on all matters relating to hydraulic mining in California. The outcome of this and similar experience was an able and well-known work on "Hydraulics."[1]

Mr. Hamilton Smith was also engaged in connection with various other mines on the Pacific Coast, did much to bring about the cheap manufacture of high explosives on that coast, and took an active part in the establishment of the Vulcan Powder Works. In 1881 he reported on the El Callao Mine in Venezuela for Messrs. Rothschild, and as Consulting Engineer he subsequently designed and superintended the construction of the machinery and appliances for that mine.

In 1885 Mr. Hamilton Smith established himself as a mining engineer in London in partnership with Mr. de Crano, with whom he founded in the following year the Exploration Company. As Manager of that Company he was actively interested in gold mining in South Africa, and took part in the formation of the Consolidated Deep Levels, the Transvaal and General Association, and other enterprises. The results of his investigations on the Rand and those of Mr. H. C. Perkins led to the formation of deep-level mining companies, the working of which he described at some length in an article in the *Times* of the 17th January, 1893. He was also connected with the Alaska Treadwell Gold Mining Company and the Anaconda Copper Mining Company. After the death of Mr. de Crano in 1895 Mr. Hamilton Smith entered into partnership with Mr. H. C. Perkins, the firm having their head office in New York. At the time of his death he was engaged in the development of the Mariposa grant in California.

In 1890 Mr. Hamilton Smith associated himself with Sir Benjamin Baker and Mr. John G. Meiggs in the promotion of the Central London Railway, and continued to take great interest in the work, both from an engineering and financial point of view, until his death. The success of the undertaking was largely due to his untiring efforts in interesting powerful American and other financial institutions in the promotion of the line.

Some indication has been given here of Mr. Hamilton Smith's ability as an engineer. His success was due to untiring energy, firmness of will, and great self-confidence. But while seeking to shape his own career, he was ever ready to help others and to give credit to those with whom he worked. He was a Member of the

[1] A copy of this book is in the Library of the Institution.

American Society of Civil Engineers and of the American Institute of Mining Engineers.

Mr. Hamilton Smith was elected a Member of this Institution on the 7th February, 1888.

CHARLES TYLDEN-WRIGHT, youngest son of the late Rev. E. C. Wright, rector of Pitsford, Northamptonshire, and perpetual curate of Bradley, near Stafford, was born on the 24th April, 1832. After being educated at Marlborough College and at the Royal School of Mines, he studied at Freiburg in Saxony and at Liége. In 1857 he became Assistant to Mr. John Lancaster at the Kirkless Hall Collieries, Wigan, and in 1860 he was appointed by the Duke of Newcastle Resident Engineer and Managing Director of the Shireoaks Colliery, one of the deepest and most extensive collieries in the midland counties, raising half-a-million tons per annum. In the same year, on his marriage with Elizabeth, only child of Lieutenant-Colonel Sir J. M. Tylden, of Milstead Manor, Sittingbourne, he assumed the name of his wife's family in addition to his own.

Mr. Tylden-Wright remained at Shireoaks until 1886, when he was appointed Chief Agent of the Dudley Estate during the minority of the present Earl. He held that post until 1890. At the time of his death, which took place at Mapperley Hall, Nottingham, on the 8th August, 1900, he was Chairman of the Shireoaks Company, a Director of the Monckton Main Collieries, of Messrs. J. and G. Wells, Limited, and of the Sheffield and South Yorkshire Navigation Company, and Viewer to the Duchy of Lancaster in the West Riding of Yorkshire, to the Duke of St. Albans, and to Mr. Webb, of Newstead Abbey. He also served as a Justice of the Peace for the counties of Nottingham, Worcester and Stafford.

Mr. Tylden-Wright was elected a Member of the Institution on the 4th December, 1883.

SAMUEL UTLEY, born on the 27th May, 1836, was the son of Mr. Jonathan Utley, who conducted a private educational establishment at Sowerby Bridge, in Yorkshire, where he was also postmaster and registrar. After being employed for two years in an Engineering Tool Works, the subject of this notice served a

pupilage to Mr. Richard Carter, of Halifax, from 1854 to 1857, during which time he was occupied on the construction of road-sewers, railway, and other works. From 1857 to 1859 he was engaged on the Bradford Waterworks as Engineer to the contractors for 6 miles of tunnel, 5 miles of conduit, including intercepting weirs, aqueducts, 1 mile of inverted siphons, a compensation reservoir covering 100 acres, and a service-reservoir. In 1859 he was entrusted by the same firm with the charge of the construction of about 200 miles of the Great Indian Peninsula Railway; and on the completion of that contract in 1863 he returned to Halifax, where he entered into partnership with Mr. G. W. Stevenson. Together they prepared Parliamentary plans and sections, and the designs of the bridges, viaducts and tunnels for the Halifax and Ovenden Junction Railway, and were also engaged in connection with the Ripon Corporation Waterworks and the Halifax Gasworks.

The partnership with Mr. Stevenson was dissolved in 1865, when Mr. Utley was joined by Colonel Gray, with whom his association continued until 1897, since when the firm has been known as Utley, Hebblethwaite and Utley. Amongst other works Mr. Utley laid out systems of sewerage for the districts of Sowerby Bridge, Sowerby and Stainland; as Engineer to the Luddendon Local Board he designed and superintended the erection of a skew-bridge over the River Calder and other works; and, in conjunction with Messrs. John Fraser and Sons, he acted as Engineer to the Halifax High-level and North and South Junction Railways.

Mr. Utley died at his residence, Norfolk Place, Halifax, on the 7th January, 1900.

He was elected an Associate of the Institution on the 1st March, 1864, was subsequently placed in the class of Associate Members, and was transferred to the class of Members on the 14th February, 1888.

WILLIAM JOHN WILSON, born in Bombay on the 19th March, 1851, obtained his engineering training at the Royal Indian Engineering College, Coopers Hill, from which he was appointed in 1874 an Assistant Engineer in the Public Works Department of the Government of India. He was posted to the Northern Division of the Ganges Canal, and was employed on irrigation work, on the construction of drainage works, and on the repairs of Jaoli Falls on the main canal. At the end of 1875 he was transferred to the

Anupshahr Branch of the Ganges Canal, and was engaged on the construction of bridges and of the "Siana Escape," an aqueduct of 7 miles in length. From 1879 to 1885 he was employed, under the Director of Agriculture and Commerce, on the construction of wells for irrigation in the North-West Provinces and in Oudh. In 1885 he was placed in charge of the Narora Division of the Lower Ganges Canal, and in 1888 he was appointed Personal Assistant to the Chief Engineer of the Irrigation Branch, and Under-Secretary to Government for the North-West Provinces and Oudh.

Mr. Wilson's experience in India marked him as peculiarly fitted for the Egyptian Government Public Works Department, which he joined in 1892 as Inspector of the First Circle of Irrigation in Lower Egypt. In February, 1895, he was appointed Inspector General of Irrigation in Upper Egypt, and in May, 1898, Director-General of Reservoirs. His death, which took place in Cairo on the 13th August, 1900, after a short illness from meningitis, has proved a great loss to the Egyptian Government, as, owing to his intimate connection with the works from their inception, he was thoroughly acquainted with all the minute details of the great reservoirs. At the time of his death he was acting as Under-Secretary of State for Public Works, during the absence of Sir William Garstin on leave. Mr. Wilson was a man of most amiable and retiring character, and was always ready to give advice and assistance to those who appealed to him.

He was elected an Associate of the Institution on the 7th May, 1878, was subsequently placed in the class of Associate Members, and was transferred to the class of Members on the 20th May, 1890.

ROBERT WINGATE, born on the 2nd August, 1832, began his engineering career as a pupil of the late Mr. Alexander M. Ross, on the Chester and Holyhead Railway. After the expiration of his pupilage he was on the engineering staff of the Metropolitan Commission of Sewers for two years, and was next engaged from 1853 to 1856, for Messrs. Peto and Betts, on the construction of the Grand Trunk Railway of Canada. In 1856 he entered the service of that Company, and was employed on the Eastern and Central sections until 1863, when he was appointed District Engineer for Messrs. Peto and Betts on the construction of the Dünaberg-Witepsk Railway in Russia. On the completion of that work he was engaged on the construction of the East Hungarian

Railway as District Engineer for Messrs. Waring, the contractors, for whom he went to Monte Video in 1871 to act in a similar capacity on the construction of the Central Uruguay Railway. On the completion of the works in 1874 he entered the service of the Company as Resident Engineer, and from that date he had charge not only of all maintenance work, but of the construction of all new extensions, including the Eastern and Northern Extensions of the Central Uruguay line and a portion of the North Eastern of Uruguay Railway, from Pando to Minas.

Mr. Wingate retired from the service of the Company in July, 1899, and returned to England, the Board still availing themselves of his long experience and intimate knowledge of Uruguay for consulting purposes, and it was in consequence of the keen interest he took in the affairs of the Company that he made it his practice to call at the office in Finsbury Circus on the receipt of inward mails. There he died after a few hours' illness, while engaged on such an errand, on the 18th June, 1900.

Mr. Wingate was elected an Associate of the Institution on the 10th April, 1866, and was transferred to the class of Members on the 16th January, 1877.

EDWARD HENRY BOLD, born at Clitheroe, Lancashire, in 1841, began his engineering career in the shops of Messrs. Bridge and Barnes, machinists, of Accrington. In 1861 he left England for Victoria, where he was engaged for eighteen months under Mr. R. Millett in setting out and levelling roads and in surveying occupation lands in the Benalla District, Goulbourn River. In 1863 he proceeded to New Zealand and entered the Government service. He was at first engaged in constructing 8 miles of the Lawrence and Clyde Road, and acted as Inspector for the construction and maintenance of 94 miles of cart roads in the same district. In 1865 he was employed under Mr. John Rochfort, District Surveyor to the Canterbury Government, in exploring for road lines and in making surveys for a coal mine reserve on the River Grey, and in September of the same year he was appointed Assistant Surveyor and Mining Surveyor to the same Government, under Mr. Davie, Chief Surveyor of the Canterbury Province, to direct and inspect land and road surveys and works relating to alluvial gold mining. In July, 1867, he was appointed, by the New Zealand Government, Telegraph Surveyor for the North

Island, and placed in charge of the setting out and construction of about 320 miles of line through broken country.

On the establishment of the Public Works Department of New Zealand Mr. Bold was appointed in 1870 an Assistant Engineer under Mr. John Carruthers, then Engineer-in-Chief for the Colony. As Road Engineer for Taupo and the East Coast he carried out many important engineering, surveying and architectural works. In 1877 he was, in addition, appointed Resident Engineer of the Napier-Manawatu Railway, and he also acted as Engineer for the Counties of Waipawa and Hawkes Bay.

In 1878 Mr. Bold retired from the public service, but before the expiration of that year he was offered the appointment of Inspector of Telegraphs for the East Coast. That post he held until 1894, when he was transferred in a similar capacity to Auckland. There he died somewhat suddenly in May, 1900.

Mr. Bold was elected an Associate of the Institution on the 4th December, 1877, and was subsequently placed in the class of Associate Members.

FREDERICK DAVIS, eldest son of the late Mr. John Davis, of Derby, was born at Cheltenham on the 26th January, 1843. He obtained his engineering training in the works and drawing office of Messrs. Carrett, Marshall and Company, of the Sun Foundry, Leeds, and at the end of 1866 began to practise on his own account, first in London, then in Derby, and finally in Westminster. For some years he was a member of the firm of Stacey, Davis and Company, of the Phœnix Foundry and Engineering Works, Derby.

Mr. Davis retired from business some years since and devoted himself to archæological and kindred studies. He was a Member of Council of the Society of Antiquaries and an active member of the Silchester Excavation Committee. At the request of the editors of "Bygone Hampshire," he wrote an exhaustive article on the discoveries at Silchester, which was published separately in 1898 under the title of "The Romano-British City of Silchester." He had previously written a work entitled "Derbyshire Place-Names," and he was a frequent contributor to various magazines.

Mr. Davis died on the 14th July, 1900.

He was elected an Associate Member of the Institution on the 3rd March, 1885.

CHARLES FREDERICK HUGHES-HALLETT, of 41 St. Stephen's Avenue, Shepherd's Bush, London, who died on the 22nd June, 1900, aged forty-seven, was the only son of Frederick Hughes-Hallett, of Brooke Place, Ashford, Kent, solicitor. He was educated at Tunbridge Wells, Weybridge School and Weeting Rectory, Norfolk, and afterwards went to Caius College, Cambridge, where he took mathematical honours. On leaving the University in 1875 he was articled to Messrs. Easton and Anderson for five years, at the expiration of which time he was placed on their staff, and in June, 1881, was entrusted by them with the work of putting up a caisson at Cape Town Harbour. In October, 1882, he returned to England, and in the following January he was appointed Assistant Engineer to the Hydraulic Power Company, which post he held until July, 1884, when the late Mr. Thomas Hawksley, Past-President, who had always taken an interest in his career, offered him the appointment of Consulting Engineer to the Waterworks Company of Barbados. That appointment lasted for six months, and on his return to England, he became early in 1885 Managing Engineer to the Autophreptic Boiler Company. In February, 1887, he was appointed Manager and Engineer to Messrs. Lawrence & Co., of Notting Hill and St. Mary Axe, which post he filled to the time of his sudden and unexpected death from syncope.

Mr. Hughes-Hallett married in July, 1883, Josephine Laura, third daughter of the Rev. James Hamilton, of Melbourn Vicarage, Cambridgeshire, who survives him.

He was elected an Associate Member of the Institution on the 1st February, 1881.

WILLIAM HENRY CORYTON KEMPE, son of Dr. Kempe, of New Shoreham, Sussex, was born on the 18th March, 1874. He received his preliminary training as an apprentice in the locomotive works of the London, Brighton and South Coast Railway, and was subsequently engaged for two years with Mr. C. O. Blaber, of Brighton, during which time he was occupied in surveying and levelling, and acted as Resident Engineer to the Steep Grade Railway at the Dyke, Brighton. He next took charge for five months of a new outfall drain and sluice at Boston, in Lincolnshire, in connection with the Kirton Outfall Embankment, under Mr. Herbert Clarke. He was a good leveller and

surveyor, thoroughly understanding the use of instruments, and the setting out and measurement of earthworks, as well as the preparation of plans and estimates, being an accurate draughtsman, quick at calculations, with an excellent knowledge of engineering mathematics. In the year 1895 he obtained a Whitworth Exhibition of the Science and Art Department at Kensington.

In February, 1898, Mr. Kempe was selected by Mr. William Shelford as an Assistant Engineer for the projected railway between Secondi and Tarkwa in the Gold Coast Colony, and left England to take up his duties in that month. During his first term of service his work was carried out in an energetic, conscientious and intelligent manner, and after his leave of absence he returned to the Colony with promotion, serving a second period of eight months with equal credit to himself and satisfaction to the Chief Resident Engineer, being placed during this period as District Engineer in charge of a section of the line under construction. At the expiration of his second period of leave he returned to the Colony with still further promotion, but contracted blackwater fever, to which he unfortunately succumbed on the 17th July, 1900. A promising career has thus been cut short, and the profession has lost an intelligent, proficient and hard-working member.

Mr. Kempe was elected an Associate Member of the Institution on the 3rd April, 1900.

HENRY ARTHUR CASPERSZ MÜLLER, born on the 19th November, 1865, passed second in March, 1889, from the Thomason Civil Engineering College, Roorkee, into the Public Works Department of Burma. He was sent to Upper Burma, where he served principally in the Shan States, being employed in the design and construction of buildings, bridges and irrigation works, and on the alignment and construction of roads, both in the plains and in the hills. In 1899 he was engaged on canal works at Mandalay, where he died on the 1st December of that year, from sunstroke and malarial fever.

Mr. Müller was elected an Associate Member of the Institution on the 1st December, 1896.

ROBERT STEWART OLIVER, son of Mr. Andrew Oliver, a well-known agriculturist in Stratherrick in his time, was born on the 8th July, 1849. The subject of this notice served an apprenticeship of four years with Mr. William Paterson, engineer and land surveyor, of Inverness. In 1871 he entered the service of the Highland Railway Company, in which he was engaged during the greater part of his life. Under the late Mr. Murdoch Paterson he was employed on the surveys for the Sutherland and Caithness Railway, and acted as Resident Engineer on the construction of that line. He also acted in a similar capacity on the Inverness Waterworks, and surveyed and carried out the Dingwall Waterworks, Caithness Quarry and Dalmore Tramway, and various other works. He remained in the service of the Highland Railway Company until the completion of the Aviemore line, in the carrying out of which important undertaking he had a large share. Mr. Oliver had a happy gift of imparting knowledge to young men, and thus rendered service to many engineers who have since attained some eminence in the profession.

In 1899 Mr. Oliver purchased the estate of Raddery in the Black Isle district of Ross-shire, and was engaged at the time of his death, which took place at 19 Ness Bank, Inverness, on the 14th September, 1900, in effecting extensive improvements on that property, including the building of a new dwelling-house.

Mr. Oliver was elected an Associate Member of the Institution on the 6th December, 1881.

THOMAS ELLIS OWEN, born on the 31st December, 1841, was the son of the Rev. J. Owen, Rector of Llaniestyn and Honorary Canon of Bangor. The subject of this notice was appointed to the Public Works Department of the Government of India in 1861, being posted to the Allahabad Division, where he was engaged for some years on important works. In 1867 he was promoted to the rank of Executive Engineer, and in April, 1873, he obtained two years' furlough. On his return in 1875 he was posted to the Northern Bengal State Railway, and for the last five months of that year he officiated as Superintendent of Works of the Nattore Division. He then held charge of various divisions until December, 1878, when he was placed in charge of the office of Superintendent of Works, Northern Bengal Railway. From the beginning of

1880 until March, 1881, he was engaged on special duty in the Julpigooree Division. His services were then placed at the disposal of the Commissioner of the Bhagulpore Division, and he was appointed Divisional Superintendent of District Works. In July, 1886, he was appointed Engineer-in-Chief of the Benares, Cuttack, Poorie Railway surveys, with the rank of Officiating Superintending Engineer, and in December of the same year he was placed in charge of the 7th Division of the Toungoo-Mandalay State Railway. After serving for a time as Officiating Under-Secretary to the Government of Bengal in the Railway Branch of the Public Works Department, he retired in 1888, and settled in Bedford, where he died on the 5th June, 1900.

Mr. Owen was elected an Associate of the Institution on the 14th January, 1868, and was subsequently placed in the class of Associate Members.

WILLIAM WARREN SMITH, eldest son of the late Mr. William Warren Smith, of Garston Park, Godstone, Surrey, was born on the 23rd June, 1869. In June, 1888, he was articled to Messrs. James Simpson and Company, of Grosvenor Road, London, and on the expiration of his pupilage remained with that firm as an assistant. In April, 1895, he sailed for Western Australia, where he was engaged in mechanical and mining work until 1897, when he returned to England. His health not being good, he then spent some time in travelling in Spain and Portugal, and in November, 1899, he went to South Africa, and in the following January joined Roberts' Horse. After taking part in the relief of Kimberley, he died at Orange River on the 17th March, 1900.

Mr. Smith was elected an Associate Member of the Institution on the 3rd December, 1895.

ALEXANDER STEWART, born on the 10th August, 1866, received his first engineering training in the office of Mr. W. G. Lamond, of Arbroath. He then served a pupilage of four years to Mr. Alexander McCulloch, of Dundee, subsequently remaining with that gentleman as an Assistant until the end of 1885, engaged chiefly on water, sewerage, and other municipal works. In March, 1886, he was appointed an Assistant to Mr. John Cooper, Burgh

Engineer of Edinburgh, in whose office he remained until a few months before his death. Among the works on which he was engaged may be mentioned Powburn Sewerage Outfall, the Water of Leith Purification and Sewerage, outfall and irrigation works at Craigentinny, Lochrin Sewerage Extension and Irrigation, and various city improvements, including the formation of new streets, sewers, etc., and the inspection of drainage and sanitary appliances in dwelling-houses. He also held the appointment, under the Edinburgh School Board, in Leith Walk Advanced Evening School, of teacher of building construction, machine construction, mechanical drawing and geometry.

In August, 1899, he began to practise on his own account in Edinburgh, and was acquiring an extensive business when he was unfortunately attacked by an illness which proved fatal on the 6th March, 1900.

Mr. Stewart was elected an Associate Member of the Institution on the 1st December, 1891.

HUBERT TOWNSEND STORRS, born on the 2nd December, 1872, began his engineering career as a pupil in the works of the Great Northern Railway Company at Doncaster. By diligent study out of hours he obtained a County Council scholarship, which enabled him to take up the engineering course at the Yorkshire College, Leeds, at the end of which course he graduated B.Sc. of Victoria University. In September, 1897, he entered the works of Messrs. Stothert and Pitt, of Bath, and for eighteen months was engaged there in designing cranes and block-setting plant. He was next employed for a brief period in London in preparing plans for bridges under his cousin, Mr. Frederic Gleadow, and towards the end of 1899 he was appointed to the staff of the North Eastern Railway Company under Mr. W. J. Cudworth.

Mr. Storrs' career was unfortunately cut short prematurely by an attack of blood poisoning, which proved fatal on the 19th May, 1900.

He was elected an Associate Member of the Institution on the 6th December, 1898.

CHARLES BARRY, born on the 21st September, 1823, was the eldest son of the late Sir Charles Barry. After being educated at Sevenoaks Grammar School he was engaged for some years as an assistant to his father on the new Palace at Westminster and other important works. In 1849 he commenced business on his own account, in partnership with the late Mr. R. R. Banks, and acquired an extensive and varied practice, both as an architect and as a surveyor. Since 1858 he held the post of Architect and Surveyor to the Dulwich College Estate, which was developed and improved under his direction; he erected the new College, altered and added to the old College, and built two large churches and several houses on the estate. In 1880 he was appointed architect to the Duke of Newcastle's trustees for large additions to Clumber House.

Among Mr. Barry's public works may be mentioned New Burlington House, Piccadilly, for the Government; Dulwich College; the Royal Exchange roof for the Gresham Committee; and the Alexandra Wing and Grocers' Wing of the London Hospital at Mile End, the estate of which he managed for several years. He had considerable experience in compensation and in light and air cases, both as a witness and as an arbitrator, and was frequently called on to act as assessor in important architectural competitions, including that for the Glasgow Municipal Buildings.

Mr. Barry acted as a Commissioner at two of the International Exhibitions at South Kensington, and in 1878 he was appointed British Commissioner for Architecture in the Fine Arts section of the Paris Exhibition. In recognition of his services on that occasion the French Government, at the instance of the Prince of Wales, created him an officer of the Legion of Honour.

Mr. Barry was elected President of the Royal Institute of British Architects in 1876, and in the following year he was awarded the Queen's Gold Medal of that Institute. He was also a Member of the Society of Antiquaries, a Member of Council of the Society of Arts, and an Honorary Member of the Imperial and Royal Academy of Arts of Vienna. He died at Worthing on the 2nd June, 1900, in his 76th year.

Mr. Barry was elected an Associate of this Institution on the 4th December, 1894, and was the architect of the present building of the Institution.

Sir THOMAS McILWRAITH, K.C.M.G., LL.D., died at his residence 208 Cromwell Road, South Kensington, on the 17th July, 1900. Born in 1835, he was the second son of the late Mr. John McIlwraith, of Ayr. After being educated at Ayr Academy he proceeded to the University of Glasgow, with the intention of entering one of the learned professions; but hearing of his elder brother's commercial success in Melbourne, he emigrated to Victoria in 1854. On his arrival in that Colony he joined the engineering staff of the Government, and was engaged in the construction of the Geelong, Ballarat, Melbourne, and Sandhurst Railways.

In 1861 Mr. McIlwraith began to be largely interested in land in Queensland, and in 1870 he finally settled in that Colony, where he was returned to the Legislative Assembly. In January, 1874, he became Minister of Public Works and Mines, but resigned in the following October. In 1877 he was recognized as the leader of the opposition, and on the defeat of the Douglas Ministry in January, 1879, he became Premier and Colonial Treasurer. In 1881 he visited England, and succeeded in making a contract with the British India Steam Navigation Company for the establishment of a line of mail steamers to run between London and Brisbane. During his various administrations he made strenuous efforts to carry a bill through Parliament to grant a concession to an English company for the construction of a Trans-continental Railway to the Gulf of Carpentaria, on the land-grant principle, a system he considered peculiarly well adapted for Queensland, where there are immense tracts of country awaiting settlement. He remained Premier until November, 1883, when the general election resulted in a majority for Mr. (now Sir) Samuel Griffith. Perhaps the most important event of his administration was the annexation of New Guinea on the 4th April, 1883, a step which did not receive the sanction of Lord Derby, then Secretary of State for the Colonies. Out of this incident sprang the Inter-Colonial Convention, held in Sydney in November, 1883, which formulated the basis on which the Federal Council of Australasia was ultimately established. While Premier Mr. McIlwraith was first Colonial Treasurer and then Colonial Secretary, in which capacities he did much to develop the resources of the Colony by initiating new railways and other works. In recognition of his services he was created K.C.M.G. in 1882. The University of Glasgow had already conferred on him the honorary degree of LL.D., and in June, 1884, he and his elder brother, being on a visit to Scotland, were presented with the freedom of Ayr.

Sir Thomas McIlwraith retired from public life in 1886, but re-entered it in 1888, when he headed the poll for North Brisbane by a large majority over the Premier, Sir Samuel Griffith, whom he succeeded for a short time. During this period the well-known dispute arose with the Governor, Sir Antony Musgrave, as to his prerogative of mercy in the case of convicted criminals. Sir Thomas contended that the Governor had no choice but to follow the advice of his Ministers in these matters, whilst the latter claimed to exercise an independent discretion. The point was subsequently decided by the Colonial Office in Sir Thomas McIlwraith's favour. He resigned his post in November, 1888, owing to ill-health, and travelled to China and Japan. In 1890 he became treasurer in the administration of Sir Samuel Griffith, and he was again Premier of Queensland from 1892 to 1893, when he finally retired. From that time he was an invalid, and vainly travelled over the Continent in search of health.

A thorough Scot, Sir Thomas McIlwraith had the kindly qualities of his race. To the last he took a keen interest in men, books and affairs, and nothing pleased him more than to discuss current politics with the Colonial statesmen and others who visited him at Kensington.

Sir Thomas McIlwraith was elected an Associate of the Institution on the 6th December, 1881.

JOSEPH BOND MORGAN, born on the 27th January, 1834, was educated at the Liverpool Collegiate Institution. After serving an apprenticeship to Messrs. Brown, Hunter and Co., he started in business on his own account as a cotton broker in 1857. In 1864 he joined partnership with Mr. William Dickinson, under the style of Morgan, Dickinson & Co., but in 1867 the partnership was dissolved and the firm was thenceforth known as J. B. Morgan and Co. Mr. Morgan took a leading part in the establishment of the Clearing-House and Bank in connection with the Cotton Brokers' Association; he was one of the first Directors of the Cotton Brokers' Bank and in 1878 was elected President of the Cotton Brokers' Association.

Mr. Morgan devoted great energy and perseverance to developing in this country the means of communication by telephone. He was for some years Managing Director of the United Telephone Company, and in that capacity he did much to introduce the use of the telephone in Liverpool.

Mr. Morgan was elected a member of the City Council of Liverpool in 1881, and in 1890 he served the office of Mayor. In the same year he was appointed a Justice of the Peace, and, for services rendered to the Greek community in Liverpool, he received the gold cross of the Order of the Saviour. He also took an active part in the promotion of the volunteer movement in Liverpool. Mr. Morgan died on the 20th April, 1900, at Downs Hill, Runfold, near Farnham, where he had been living in retirement for about two years.

He was elected an Associate of the Institution on the 6th December, 1887.

DANIEL PIDGEON, born at Weymouth in 1833, was educated at Crewkerne Grammar School, and became an articled pupil of Messrs. Barrett, Exall & Andrewes, of Reading. On the expiration of his articles Mr. Pidgeon was for a time in the office of Mr. Thomas Hawksley, Past President, as a draughtsman, and was subsequently employed by Messrs. Cochrane & Co., of Dudley, until 1862. During that period he was engaged in working out the details and on the erection of Westminster Bridge, and in the extension of the South Eastern Railway to Charing Cross, including the Charing Cross Bridge over the river.

In 1862 Mr. Pidgeon settled at Banbury as junior partner in the works of Mr. (now Sir) Bernhard Samuelson. At that time the firm was engaged in introducing its first successful self-raking reaping machine, and Mr. Pidgeon's talent for organization was of great use in devising arrangements to meet the rapid increase in the demands on the resources of the firm. After the Franco-Prussian war there was a large demand for agricultural implements in this country, from which those makers who were best prepared to avail themselves of it derived great benefit. The technical management of the business was in Mr. Pidgeon's hands for fourteen years, at the expiration of which time he left the firm and practically retired from active work.

Mr. Pidgeon possessed an unusually active mind, and the deep interest he took in the progress of science, as well as in literature and the current topics of the day, fully employed his leisure. A frequent and appreciative visitor to the United States, he recorded his impressions and experiences of that country in two books, which met with a favourable reception on both sides of the Atlantic. He was a Fellow of the Geological Society and a

Member of Council of the Royal Agricultural Society, to the Journals of which he contributed Papers.

During the last few years of his life Mr. Pidgeon suffered from an affection of the heart which made much physical exertion impossible. He died on the 13th March, 1900, at Assuan, Egypt, after a few days' illness.

Mr. Pidgeon was elected an Associate of the Institution on the 7th February, 1871.

*** The following deaths also have been made known since the 28th July, 1900:—

Honorary Member.

SAXE-COBURG-GOTHA, H.R.H. the Duke of, K.G.; *died* 30 July, 1900.

Members.

DAVIDSON, ALFRED; *died* 8 August, 1900.

SMITH, JAMES WILLIAM; *died* August, 1900.

Associate Members.

DUNLOP, HENRY HERBERT GRAHAM; *died* 28 July, 1900.

PORTER, JOHN; *died* 28 June, 1900.

Information as to the career and characteristics of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 29 September, 1900.

Sect. III.

ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

Public Works in Bosnia and Herzegovina. Émile Demenge.

(Revue générale des Sciences, April 15, 1900, p. 472.)

Since the occupation of the provinces by Austria, the Public Works Department, which forms one of the four principal branches of the administration, has been placed directly under the Finance Ministry. Each of the four sections of the Works Department—buildings, roads, hydraulic works, and railways—is dealt with by the Author in detail. Until the year 1878 there was but one railway in the country from Doberlin to Banjaluka, the first section of the line projected by Baron Hirsch to Salonica; this railway is of the normal gauge. By reference to a map an account is given of the network of narrow-gauge lines which have been recently constructed, and which constitute the K. K. Bosnabahn and its extensions. The total length of these railways, which are all of 30-inch gauge, is 413 miles. In some places the gradient is so severe as to entail the use of rack-rails. Diagrams are given of the locomotives and of the toothed wheels employed, together with details of the rolling stock. Before 1879 there were no roadways of solid and sound formation, but since then a new system of roads has been completed which complies with all modern requirements. The roads are divided into three categories—main roads, secondary roads, and horse tracks—and the formation and dimensions of each are described. Photographic illustrations are given of some of the principal bridges, all of them of recent construction. Much damage was formerly caused by floods, and, in order to remedy this state of things, important works have been undertaken to regulate the flow of certain of the rivers, the Drina, the Miljačka, the basin of the Mlade, and the Kline. An account follows of these various works, as also of those undertaken for the water-supply of some of the principal towns. Illustrations are given of the central electric station at Sarajevo, with details concerning the mode of distributing the current for purposes of lighting and traction. In conclusion, the Author enumerates the public buildings which have been provided under the new régime.

G. R. R.

On the Most Convenient Gauge for the National Chilian Railways (four Papers). MONTT, SANTA MARIA and FUENTE.

(Anales del Instituto de Injenieros, Chili, 1900, p. 45 *et seq.*)

In the first Paper by Mr. Montt, which was read before the Institute of Engineers at Santiago de Chile, the Author discusses the question of the best gauge for the future lines in Chili; he was prompted to deal with the subject by the choice of a gauge of 0·75 metre (2·46 feet) on behalf of the Public Works Department for the railway from Alcones to Pichilemu, a line about 18·6 miles long; this gauge was recommended by Mr. Huet for the new State railway in the north of Chili. He considers the subject from the points of view of practical convenience, military importance and initial cost. His conclusions are that military considerations are of great importance; that on level ground a line of 0·75 metre (2·46 feet) gauge is no cheaper than one of 1 metre (3 feet $3\frac{3}{8}$ inches); that in mountainous districts a saving in initial cost of 18 per cent. can be made by adopting a gauge of 0·75 metre and radius of 70 metres (230 feet) for curves, but this will decrease the speed by 25 per cent. In the central zone it will be difficult to alter the existing gauge of 1·68 metre (5·5 feet), but that this gauge need not be retained for branches. He therefore concludes that the adoption of 1 metre-gauge from Calera to the North is justified; that it is unwise to alter the metre-gauge lines already constructed; the 1·68 metre gauge line from Valparaiso to Puerto Montt should be retained; that the gauge of the new lines in the North should be 1 metre.

This Paper is followed by one written by D. V. Santa Maria, who favours the metre-gauge and objects to the use of the 0·75 metre gauge, as it needs special locomotives which are difficult to repair, and needs special fuel, such as coke.

This Paper is followed by a second Paper by Mr Montt upon the relative costs of the lines of 1 metre, and 0·75 metre-gauge. Tables of the costs are given for a large number of actual lines in Chili, but these cannot well be summarised.

This Paper is followed by one entitled "What Gauge should be adopted in Chili for new lines," by Mr. J. M. de la Fuente. The Author gives a Table of the various lines in Chili, from which it appears that there are now 2,576 kilometres (1,600 miles) in all distributed as follows:—600 kilometres (372 miles) of 0·76 metre (2·5 feet) gauge; 498 kilometres (310 miles) of 1 metre-gauge; 508 kilometres (315 miles) of 1·067 metre (3·5 feet) gauge; 684 kilometres (425 miles) of 1·47 metre (4·82 feet) gauge; 123 kilometres (76·5 miles) of 1·27 metre (4·18 feet) gauge, and 163 kilometres (101 miles) of 1·676 metre (5·5 feet) gauge, and he considers that for the new lines in the North the metre gauge would be the best.

E. R. D.

Projected Railway Bridge over the Little Belt.

(Ingeniøren, Copenhagen, 1899, pp. 339–342.)

The Danish State Railway authorities have lately revived the project of a railway bridge over the Little Belt between Jutland and Funen, to take the place of the existing ferry, by which the railway journey between Copenhagen and the mainland is at present interrupted, and to meet the requirements of the increasing traffic. Two provisional designs have been worked out in detail, with the necessary calculations, allowing a clear headway of 134 feet.

One plan is for a suspension bridge with roadway stiffened by lattice girders. It would have a centre span of 300 metres (984 feet), and two side spans of 169·6 metres (556½ feet) each, making the total length of the iron bridge 639·2 metres (2,097 feet) between the land piers. Each land pier is 65 metres long (213 feet), and is approached by a masonry viaduct on three arches of 40 metres span (131 feet) and piers 5 metres thick (16½ feet). The suspending cables are carried over lattice towers 37·5 metres high (123 feet), erected on the tops of the two sea-piers, and are anchored in the land piers. Each cable consists of 9,144 steel wires of 4 millimetres diameter (0·16 inch), having a minimum tensile strength of 12,000 kilogrammes per square centimetre (76 tons per square inch), which are made up into 127 strands of 72 wires; each strand is placed individually in the cable, and the whole is bound round with steel wire. To diminish lateral vibration the two cables are inclined inwards towards each other, so that they hang in planes making angles of 1 in 10 with the vertical. The two lattice girders carrying the roadway suspended from the cables are 11·5 metres high (37¾ feet) and 9·8 metres apart (32 feet); they are constructed with top and bottom members of box section, united by a double system of channel-bar diagonals and verticals. The bridge is calculated for a possible uniformly distributed load of 3·64 tons per metre (1·1 ton per foot run), with an addition of 2·06 tons per metre (0·62 ton per foot) for a length of 32·64 metres (107 feet), corresponding with two locomotives and tenders. The stress allowed for the cables is 3,000 kilogrammes per square centimetre (19 tons per square inch), and for the girders 1,050 kilogrammes (6⅔ tons). The whole weight of the ironwork is 9,325 tons, of which about 1,625 tons will come on the cables. The foundations for the two sea-piers are to be sunk 5 metres (16 feet) into the ground by the aid of pneumatic pressure, and of large iron caissons built on shore and floated out into position. The piers will be built of shingle concrete faced with granite, and will have a cutwater at each end to break drift-ice. The land piers will each be double, one behind the other, connected by an arch. Beyond them on each shore will be a viaduct carried on three concrete arches of 40 metres span

(131 feet). The cost will amount altogether to about 15,600,000 kroner (£866,667), of which 5,325,000 kroner (£295,833) will go for superstructure, 7,040,000 kroner (£391,111) for substructure, and the rest for land viaducts, and alterations of existing lines and stations.

The other design is for a cantilever bridge, having a centre span of 350 metres (1,148 feet) and two side spans of 181 metres (594 feet) each, with a land pier and viaduct at each end, making the total length of the bridge 712 metres (2,336 feet). The superstructure consists of two main cantilever girders 12 metres apart (39 feet), each 321 metres long (1,053 feet), with one end anchored on the land pier, and the other projecting 140 metres (459 feet) over the centre span; the two overhanging ends carry the central length of 70 metres (230 feet). Over the two sea-piers the girders are 40 metres high (131 feet), over the land piers 12·5 metres (41 feet), and in the middle of the centre span 9 metres (29½ feet); their outlines are arcs of circles. The top and bottom members are of rectangular box section; and of the box itself the top and bottom are plates and angle-bars, and are connected by four vertical lattice walls. The verticals and diagonals are likewise of rectangular box-section, with angle-bar corners and lattice sides. Cross girders 2 metres high (6½ feet) are placed at every vertical; they are not secured to the main girders, but rest on cradles on the lower members of the latter, so as to avoid extra strain from the load being one-sided in a bridge carrying two lines of railway. The rail bearers are plate-iron girders 1 metre high (3¼ feet), resting on sliding beds to allow of expansion, and carrying the cross sleepers, with longitudinal baulks alongside each rail in lieu of guard rails. Laterally the bridge is stiffened against wind-pressure by lattice cross-bracing at top and bottom of the main girders and between the verticals. For the same load as in the suspension design, the stress allowed for the main girders is the same, namely 1,050 kilogrammes per square centimetre (6⅔ tons per square inch). The weight of the ironwork is 12,400 tons. The two sea-piers are similar to those for the suspension design. The land viaducts are of iron lattice girders, resting on iron piers built on granite foundations. The cost is estimated at 6,040,000 kroner (£335,555) for superstructure, 5,225,000 kroner (£290,278) for substructure, and 4,035,000 kroner (£224,167) for land viaducts and alterations of existing lines and stations: total 15,300,000 kroner (£850,000).

For some such bridge a bill was introduced, but was not proceeded with. In view of the magnitude of the interests concerned, it is hoped that the legislature will invite competitive designs, somewhat on the general lines of one or other of the projects above summarized.

A. B.

A New Locomotive Shed on the Swiss North Eastern Railway at Zurich. E. EGGER.

(Schweizerische Bauzeitung, 1900, p. 143. Figs.)

Owing to the increase in quantity of the rolling stock upon the North Eastern Railway, it was decided to build a new locomotive shed, and the site chosen was at the junction of the Zurich-Winterthur and Zurich Rapperswil lines. The building is of rectangular form with seven through lines, each with a pit all its length, and standing for seven locomotives. This is considered sufficient for the 100 engines which are used at the Zurich centre. The standing room for each engine is taken at 59 feet, and the accommodation suffices for forty-nine engines with separate tenders, or for 35 such engines, and 28 engines with combined tenders. The centre of the building has three cross tracks, upon which works a traverser 52·5 feet long, actuated by steam power and also by hand. Outside the building at the west end a turntable 52·5 feet diameter is fixed and also worked by power, and the lines at the east end communicate directly with the station. Over each locomotive stand there is a special chimney under which the locomotive chimney must be placed. On the first floor there is living accommodation for the running shed foreman and also a number of bedrooms for drivers, stokers and cleaners. The driver and stoker of each engine have a bedroom to themselves so as to be undisturbed by the later arrival of other workmen. There are complete stores and a repair workshop. The whole building is heated upon the low-pressure steam principle, and there are two separate boilers, one for the sheds and the other for the rest of the building. The former plant is only used when the temperature is very low, as sufficient heat is usually given off by the locomotives themselves. Two of the lines in the shed are used for locomotives undergoing repairs, and a channel below the floor level is arranged across these lines, and it is provided with a track upon which runs a carriage with a hydraulic lift; this apparatus serves for the removal of the wheels and axles to the turning lathe. The hydraulic power is provided by a belt-driven pump, and a mixture of one-half water and one-half glycerine is used to prevent freezing. The fire-boxes and smoke-boxes are always cleaned over pits in the open air so as to diminish the annoyance in the sheds.

E. R. D.

The Electric Railway at the Paris Exhibition. J. Laffargue.

(La Nature, 9 June, 1900, p. 21.)

This railway, placed alongside the moving platform[1] in the form of a closed circuit, is partly carried on wooden supports, partly in cuttings and partly, in the case of the viaducts, constructed on metal girders. The maximum curves have a radius of 2 chains, and the greatest gradient is 4 per 100. It is a single line with Vignoles rails weighing 50·5 lbs. per yard on a gauge of 3·28 feet. The current is conveyed by means of a third rail of the same section, fixed at the end of the sleepers on porcelain insulators. The return current is conveyed through the rails themselves, which are well connected to each other by copper strip securely riveted. The electric energy is conveyed to the lateral rail by means of feeders, issuing from the substation on the Champ de Mars. The triphase current of 5,000 volts is at first transformed to one of 220 volts, and passing through a commutator of 450 kilowatts, it is delivered as a continuous current of 520 volts. Each train consists of a motor carriage and two coupled carriages. The motor-carriages are furnished with 2 Westinghouse motors of 35 HP. each, and weigh 8 tons. They carry 46 seated and 36 standing passengers; the coupled carriages are on bogie-wheels, and each carry 32 seated and 30 standing passengers. These trains are driven at a rate of 11·18 miles an hour, and can be arranged at intervals of 1½ minute apart. Each carriage is furnished with triple brakes.

G. R. R.

Lubrication of Locomotives. F. Wagner.

(Organ für die Fortschritte des Eisenbahnwesens, 1900, p. 62.)

This Paper deals with the question of the lubrication of the pistons and slide valves of locomotive engines, and contains a description, with drawings, of an improved automatic arrangement for introducing the lubricant in the form of spray. The oil, contained in cylindrical vessels, is pressed forwards through a small nozzle, when it is caught up by a steam jet and carried forward in a finely divided state, either (1) to the slide valve when the engine is running in steam, or (2) to the cylinder when the engine is "coasting."

The containing cylinders and spray producers are at the cab end of the engine, the valves for directing the lubricant to the slide valve and cylinder are situated near the cylinders.

The Author further discusses the influence of the increased use

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxvii. p. 470.

of high-pressure steam on the lubrication of locomotives, and states that, while to-day an oil is required that will not lose its lubricating qualities at 300° C., the oil actually used suffers dissociation at 190·5° C., and is consequently in many cases quite useless as a lubricant.

This circumstance and not the high pressure on the valve seat is, in the Author's opinion, the source of the defective lubrication, and the excessive wear on the face of the slide valve and ports.

The remedy for this is the admixture of graphite with the lubricant, and the Author, after stating the several advantages possessed by graphite for lubrication purposes, mentions a test experiment in which one locomotive of a group of twenty was provided with graphite lubrication for the pistons and slide valves. The cost of lubrication for this engine was 0·59 pfennige per kilometre, the coal consumed 12 kilograms per kilometre, while for the others the corresponding figures were 0·82 pfennige per kilometre, and 15 kilograms per kilometre.

Also, the locomotive using graphite lubrication was, after 18 months' constant running, in as good condition as when it left the repairing shops.

W. B.

Experimental Runs with Locomotives. Leitzmann.

(Verhandlungen des Vereins zur Beförderung des Gewerbefleisses, 1900, p. 35.)

The Author contends that the attempt to standardize locomotives must be abandoned, and that the necessity of a proper knowledge of locomotives and their possibilities necessitates the systematic examination and testing in running of all builds of engines. His paper forms a complete set of instructions for carrying out these investigations, which include the determination of the steam produced and used under all possible conditions as to gradients, speeds and weights of trains; the fixing of the utmost limits of steam-production, tractive force, horse-power, adhesion in various conditions of the weather; steam and pressure losses; train resistance; quality of fuel and amount used, and the easy running or otherwise of the locomotive.

It also includes generally the advantages and disadvantages of the particular engine under trial, the most suitable classes of work for it, and the best way of handling it.

The train resistance is assumed to be expressed in the form:—

$$a + b v^2 + c,$$

where v is the velocity and a, b and c are constants, the last representing the effect of the gradient, the two constants a and b are to be determined by runs on two different gradients without steam, the run being maintained on each gradient until the speed remains constant.

The steam and water losses are due to the injectors, water used for spraying on the coals, etc., brake pump, steam-sander, safety-valve, etc., and may amount, as in a case cited by the Author, to 20 per cent. of the total.

The determination of the maximum performance of the locomotive is one of the most important objects to be effected. The steam used is:—

$$M' = \frac{10\, d^2 h}{D}\, e\, v\, \gamma,$$

where d is diameter of piston in metres, h is the stroke of the piston, D is diameter of driving wheel, e expansion in percentage of cylinder volume filled, v speed in kilometres per hour, γ specific weight of steam.

The steam used in any particular locomotive is thus proportional to $e\,v$.

By the use of this quantity of steam, a certain vacuum ϕ is produced, and corresponding to this an amount of steam M''. M'' can be increased at will by increasing $e\,v$ but only so long as M'' is greater than M', When $M' = M''$ then the condition of things is steady and the locomotive is at its maximum performance.

The above formula gives too small results with low speeds and too large values with high speeds. In an example of a compound goods engine, the deficiency at 12 miles per hour was 1½ per cent. while the excess at 22 miles per hour was 33 per cent.

The Author deduces an approximate formula for the resistance due to side winds, which is as follows:—

$$Z = \frac{\mu\, P\, \rho_o}{r} \text{ per axle.}$$

μ is the coefficient of friction,
P side pressure of the wind per axle,
ρ_o distance of the centre of gravity of the rubbing surface from the instantaneous centre of rotation of the wheel,
r the radius of the wheel.

Taking an example with a wind blowing about 20 miles per hour, the Author deduces that with a train speed of 12½ miles per hour, the resistance is increased 48 per cent. by the side wind.

The accurate determination of the total locomotive resistance can only be accomplished by the use of the indicator and dynamometer. If we call Z_1 the locomotive resistance, Z the indicated tractive force, and Z_2 the train resistance at the couplings, then $Z_1 = Z - Z_2$.

A method of obtaining the locomotive resistance, and at the same time the total train resistance, is by the use of the following formula:—

$$\text{Total tractive force} = C_1\,(a_1 + b_1\, v^2 + c_1\, \epsilon) + C\,(a + b\, v^2).$$

C_1 is the weight of the locomotive, and C that of the train. Runs are made on five different gradients, without steam until a

constant speed is reached, and five equations are thus obtained to give the values of the five constants in the above expression.

The Author further considers mathematically the various processes going on in the cylinder in simple and compound locomotives, and concludes with an appendix of diagrams, tables, etc., for use in actual testing.

W. B.

Improved System of Rail-fastenings. GARTAULT.

(Revue Générale des Chemins de fer, 1900, p. 138.)

Some few years ago, before the import duties on foreign material came in force, the Paris-Lyons and Mediterranean Railway Company held a very large stock of Baltic pine sleepers, the extensive forests of the Landes also furnish an almost inexhaustible supply. The drawback to the use of pine sleepers is the fact that in consequence of decay the dog-spikes or screws soon work loose. This defect is overcome by the system invented by Mr. Albert Collet and adopted by the above railway. A wooden screw of hornbeam or other tough wood, 2·08 inches in diameter at the top and 1·38 inch at the bottom, the thread having a pitch of 0·59 inch and a depth of 0·197 inch, with an iron band to prevent splitting and a hole down the centre, is screwed into the pine sleeper, and into this the dog-screw is fastened. The procedure with old sleepers is to bore out the old hole with a 1·38-inch auger, tap the new hole, screw in the wooden 2-inch screw, and into it the dog-screw; with new sleepers the eight holes are drilled at one operation before creosoting.

From a series of experiments made with a Collet dynamometer,[1] the increase in the holding power with these wooden cores was found to be 29 per cent. for Baltic, and 39 per cent. for the Landes pine sleepers, while with old sleepers 8 years in the line, the percentage is much greater, being 80 for pine, 33 for beech, and 62 for oak. It is also found that the fastenings last much longer, as the moisture does not penetrate the wood, and the bed-plates resting on four hard-wood screws do not work into the sleeper.

In 1895 the first experiments were made; in 1896 4,500 were fixed, in 1897 8,000, and since then 3 million have been supplied by Mr. Collet, who by the use of improved machinery has so reduced the cost that they have been universally adopted by the Paris-Lyons and Mediterranean Company, and are being adopted by the Northern, Eastern, and Western Railway Companies.

W. A. B.

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[1] Revue générale des Chemins de fer, September 1899.

Colours for Railway Signal Lamps. J. Wefring.

(Teknisk Ugeblad, 1899, p. 455.)

In view of the increasing signalling requirements at the larger railway stations in Norway, the distinctive colours for the signal lamps are becoming a more and more important question. Ever since they were fixed at the Birmingham congress in 1841, three colours have been adopted as international: white for "line clear," red for "danger" or "stop," and green for "caution." Their luminosity is about in the ratio of 1:3:5, that of violet being 7. The white light for "line clear" is objectionable, because, if the lamp happens to be extinguished, any other white light in the neighbourhood may be mistaken for the signal; and accident has resulted therefrom. On the Planegg-Weilheim section (37 kilometres = 23 miles) of the Bavarian State railways, near Munich, a green light has been experimentally tried since May 1899 for "line clear," and violet for "caution." The change, though previously proposed in 1894, had not been then approved. In America it is considered there are difficulties attending the use of violet as a third colour: and therefore, while there is unanimity in regard to retaining red for "stop," the other two colours are left to the choice of the several railways. It has also been suggested to abolish the "caution" signal at night; but as such a step would not readily accord with the general automatic working of the signals, it has been given up.[1]

A. B.

Royal Bavarian Saloon Carriage. E. Schrauth.

(Organ für die Fortschritte des Eisenbahnwesens, 1900, p. 66.)

This Paper is a description of a saloon carriage built for the Prince Regent of Bavaria. It has two six-wheeled bogies. The total length over the buffers is 68 feet 3 inches. The body of the carriage is supported on sixteen cross springs, twelve longitudinal springs, which again are supported at their ends by twenty-four volute springs, or fifty-two springs in all. The bogies are of iron, the underframe of the carriage of timber. There are two saloons, a front and a main saloon, then sleeping-room, two compartments for attendants, and accommodation for servants. The furnishing is of the very richest description. The lighting is by electricity, and the heating by steam. The weight is 47 tons loaded.

The article is illustrated with photographs of the saloons, detail drawings of the bogies, and contains a tabulated list with dimensions of various royal saloons.

W. B.

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[1] Since 1897 nearly all the railways in Great Britain have abandoned the use of white and purple for signals, and now only use red for "danger" and green for "line clear."—Sec. Inst. C.E.

Progress in Railway-Carriage Building in Germany.

PH. SCHÄFER.

(Organ für die Fortschritte des Eisenbahnwesens, 1900, p. 2.)

This article describes a number of carriages which form an advance on the four- and six-wheeled coaches with short bodies. The first is a third-class compartment carriage with two four-wheel bogies for the Prussian State railways. The total length is 17,286 millimetres (56 feet 6 inches). There are twenty seats, holding from three to five people each, the total number of passengers being eighty. There are three lavatories, accommodating all the passengers. The weight of the carriage empty is 28,430 kilograms (28 tons). The weight on an axle when full is about 8½ tons. The cost per passenger is on the average about £15.

The Author compares this carriage with a standard four-wheeled coach, and while the bogie carriage will cost more and weigh more per passenger, it is better suited for high speeds and sharp curves, and will run a longer mileage without being laid aside for repairs.

A third-class drawing-room bogie carriage for the Gothard Railway is somewhat similar to the above in general dimensions. One point mentioned is that the wheels are put on so that their heavier parts are towards the same side of the axle, and the wheels and axle combined are not out of balance more than about 1½ lb.

The next described is a composite bogie carriage for the Prussian State railways. It has eight compartments and four lavatories, and accommodates in all fifty-eight passengers, five first-class, twenty-one second-class, and thirty-two third-class, or in the somewhat unusual proportion of 1:4:6. The carriage body is 54 feet long. The weight of the carriage is 31 tons, and cost £1,350.

Another carriage very similar to the above is for first and second-class passengers only, total number forty-one.

W. B.

Progress in Railway-Carriage Building in Switzerland.

C. P. SCHÄFER.

(Organ für die Fortschritte des Eisenbahnwesens, 1900, p. 87.)

This article describes three carriages of a type lately introduced on the Gothard Railway. The external dimensions and weight empty are the same for each of the three coaches, but, as the class of passengers varies, there are differences in the internal arrangements and fittings. The classes of passengers carried by the three coaches are respectively first-class only, first- and second-class, second-class only. The type is that of a drawing-room car, that is, there are seats along each side, with a passage up the centre,

and side doors toward each end. At the ends are platforms and vestibules for communication with adjacent coaches. The body of the car is carried on two four-wheeled bogie-trucks, having a wheel base of 2·5 metres (8·20 feet). The extreme wheel base is 16 metres (52 feet 6 inches). The total length outside buffers is 19,640 millimetres (64 feet 4 inches), the length of the body being 16,490 millimetres (53 feet 10 inches), the maximum width over the footboards 2,980 millimetres (9 feet 9¼ inches). The maximum height above rails is 3,850 millimetres (12 feet 7⅝ inches). There are three braking arrangements, a hand-brake on each end platform connected with the brake rods of the Westinghouse brake, an emergency brake of the Westinghouse type which can be applied from any part of the carriage, and the Westinghouse automatic. There are thus eight brake connections to each carriage. The pressure on the brake blocks can amount to 75 per cent. of the empty weight of the carriage, which is 33 tons. The heating is by steam, and the lighting by electricity. The number of passengers carried by the first-class carriage is thirty-six, by the composite first and second forty, and by the second-class forty-eight. There is one toilette compartment to each class of passengers. The cost of the carriages, including electric lighting, is £2,300, £2,100, and £1,950 respectively, or at the rate of £64, £52 10*s.*, and £40 14*s.* per passenger in each case.

W. B.

Apparatus for determining the Safe Load upon Foundations.

R. MAYER.

(Schweizerische Bauzeitung, 1900, p. 77. Figs.)

The Author designed an apparatus[1] which gave very satisfactory results, and was used upon important works; it cost £25 4*s.* The Author has now designed a hand apparatus which only costs £5, and is illustrated in the original article. It consists of three parts screwed together. The body of the apparatus is a tube, and upon this slides a second tube having a cross-head held by a strong spiral spring fitted inside the main tube; the sliding tube can be moved by a pair of arms. A set of sounders are provided, and any one of these can be screwed into the body of the instrument; the diameters of the base of the sounders vary. In use the apparatus is held vertical by the arms or handles, and pressure is put upon it in a downward direction, and this pressure is gradually increased until the sounder enters the surface of the ground to a depth of 1 millimetre, the position of the sliding tube is then noted upon a scale marked in lbs. or kilograms upon the main tube. The whole apparatus folds into a small case and only weighs 4½ lbs. It is best for two persons

[1] Schweizerische Bauzeitung, vol. xxviii., No. 22.

to use the apparatus, one observer noting the precise depth to which the sounder has entered the ground—and for this purpose there are marks upon the head of the sounder—while the other observer applies the pressure and notes the reading upon the scale as soon as the first observer gives the signal.

E. R. D.

A Wooden Bridge over the River Trême at Fribourg.

A. Gremaud.

(Schweizerische Bauzeitung, 1900, p. 87. Figs.)

The bridge described carries the cantonal road from Gruyères to Broc over the torrent of the Trême. The cantonal administration would not sanction a metallic bridge owing to the cost. The Author points out that while the vertical trusses of a bridge can be easily protected from the weather, this is not the case with the horizontal structure carrying the roadway, and particularly that part below the side gutters of the road.

The bridge crosses the stream at an angle of 75°; its span is 46 feet, and width between trusses 17 feet; the trusses are of fir on the Howe system. The cross girders carrying the roadway are of I section in mild steel weighing 29 lbs. per foot. The test load consisted of gravel evenly spread over the roadway to a depth of 8 inches, giving about 71·5 lbs. per square foot. The trusses deflected 2·2 inches under this load, and after its removal had a permanent deflection of 0·47 inch.

The cost was as follows:—

	£	s.	d.	£	s.	d.
(*a*) Piers, excavations, etc.				143	10	0
(*b*) Bridge itself:—						
Carpentry	113	14	0			
Straps, bolts, nails	32	8	0			
Metal girders and fixing same	19	13	0			
				165	15	0
				£309	5	0

E. R. D.

Two Instruments for Measuring Deformations and Deflections in Loaded Bridges. G. Mantel.

(Schweizerische Bauzeitung, 1900, p. 48 *et seq.* Figs.)

The Author states that it is generally supposed by engineers that the system of calculation of lattice girder-bridges is now so well understood that tests of actual structures are unnecessary; he considers, however, that this view is by no means correct. A

test of an actual bridge under load clearly proves that there are present other forces than those usually taken into account, and that the members are subject to bending and other stresses besides the pure tensile and compressive stresses usually calculated for. The Author has had two special instruments made to his own designs by Usteri of Zurich, for the inspection of railway bridges.

The first is a kind of clinometer or angle-measurer, consisting of two straight bars jointed together; one bar can be cramped to one of the members of the structure, while the other carries a spirit level, adjustable by means of a micrometer screw with divisions clearly marked upon it; by making a series of these observations it is easy to ascertain if deformation has occurred. The Author then describes the use of the apparatus upon a bow-string girder bridge of 180 feet span.

The second instrument is for measuring extensions in members subject to tensile stress. The Author refers to the Fränkel instrument which gives an automatic record, but he considers it too heavy and clumsy. He then refers to the Manet type of apparatus, and the improvements effected by Rabut, and criticises the mechanism. A satisfactory instrument should be suitable for use on structures subject to moving loads, but the movement of the indicator should be controlled. The instrument brought out by the Author and illustrated in the original Paper consists of a pair of special cramps suitable for fixing upon the part to be tested, a rod with suitable swivel end is connected to one cramp, the other cramp is provided with a dial and pointer upon which the extension of the part tested is multiplied a thousand-fold. The instruments appear to have given satisfactory results in actual practice.

E. R. D.

The Construction of Steel Chains for the Shwur-Platz Suspension Bridge at Budapest. J. Seefehlner.

(Zeitschrift des Vereines deutscher Ingenieure, 1900, p. 558.)

This bridge spans the Danube and carries the road connecting the Eastern Railway station with the Ring Strasse. The central span is 951·46 feet, and the two side openings 145·3 feet in width. Each pier carries two iron towers resting on cast-steel hinged bearings, and braced together. One continuous framed girder (slightly arched in the centre span) carries the roadway, which is 59 feet wide, with two tram-lines.

The distance between the axes of the chains is 65·6 feet. The links are of Siemens steel, all other parts of iron [1] supplied from the Diosgyörer Iron Works in connection with the Hungarian State Workshops under the direction of the Author. The total

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[1] The original has "Martin steel" and "Martin iron."

cost is set down at £441,176 including £10,775 for plant and machinery, 26·7 per cent. being allotted to the substructure, 61 per cent. to ironwork, 2·5 per cent. to decorative work, 0·3 per cent. to lighting, and 9·5 per cent. to sundries. The tensile strain for all steel was specified as from 30 to 35 tons per square inch, and 20 per cent. elongation for sections under 0·775 square inch; in addition to this, cold bars from 1·97 inch to 2·84 inches in width, were required to submit to binding, (*a*) round a core with a diameter twice the thickness of the bar, (*b*) and at a red or blue heat to be bent at a sharp angle and hammered flat without a flaw. No welding to be allowed. The Board of Trade furnished the drawings and dimensions, some of which are reproduced in the Paper. The links were of considerable dimensions, the longest being 34 feet; their manufacture is fully described; no shearing or punching was permitted; each set of links was put together and bored at one operation. The Paper is furnished with plans, sections, elevations, and photographs of the plant and machinery, and of the details and general arrangement of the work, together with Tables of the cost and progress of the undertaking.

W. A. B.

The Improvement of the Lower Weser.

(Archiv für Post und Telegraphie, 1900, p. 209.)

Centuries ago small craft used to ascend the Weser to the Hanse-town, Bremen, and when larger ships were built, after the invention of the compass, the lower reaches of the river and its mouth were improved about the beginning of the 15th century. From want of proper attention, however, the river-bed became gradually silted up, and at the beginning of the 17th century it was no longer possible for trading vessels to reach Bremen, and they were obliged to anchor at Vegesack about 10·5 miles lower down. In 1823 an agreement was made between the various towns upon the Weser, by which they agreed jointly to maintain the river in proper order. In 1830 a harbour was made at the mouth of the river and called Bremerhaven, but as this was 43 miles from Bremen the goods all had to be transhipped, and therefore cost 2*s*. per ton more at Bremen than if discharged there, and the river was so shallow that it was frozen every year. About 1850 an agreement was made between Prussia, Oldenburg and Bremen for deepening the course of the river, and in 1860 it was possible for vessels drawing 9 feet of water to reach Bremen. The cost to Bremen amounted to £12,500 a year for the work up to Vegesack, and the town also paid a large part of the £4,500 which was annually expended upon the other reaches. A joint commission of several of the riparian States sat in 1870 to consider the desirability of deepening the course of the river, and finally the subject was brought before the German Bundesrath and a special

commission, consisting of Messrs. Gerke, Nienberg, Heineken, and Franzius, was appointed to consider the matter, and they decided that the river course required correction from Bremen upstream as well as towards Vegesack, and the estimated cost was £1,500,000. The Bundesrath would not pass the Bill, so finally Bremen joined the Customs Union and offered to do the work herself, and in 1886 obtained authorization to deepen the course of the lower Weser to 16·4 feet, and to levy dues on all craft using it.

The article then deals with the methods by which the improvements were carried out; the section of bed chosen consisted of a trapezoidal channel between high and low-water level, and a central deeper channel in section, almost an equilateral triangle, below it in the centre. The Author describes the effects of curves and of islands in altering the section of the bed of the river. Curves were straightened, backwaters filled up, and dredging of course very largely used; in the portion Bremen-Elsfleth constructions of brickwork forming dams in the stream were largely used. Enormous quantities of brushwood, piling, and fascine work were employed, and now the specified depth of 16·40 feet has been obtained. Constant and careful work will of course be henceforth needed to maintain the river-bed.

E. R. D.

A Movable Caisson for the Repair of Dock Walls.

PIERRE DE MÉRIEL.

(La Nature, April 14, 1900, p. 315.)

An account is given of a movable caisson recently employed for the repair of the Carnot basin at Calais, designed by Mr. Charguéraud, the engineer of the works. By reference to an illustration, the Author explains the difficulties which had to be overcome in this undertaking. The outer surface of the dock walls is curved, and the caisson, which was constructed entirely of metal, had to follow the line of curvature. End walls were built up in masonry to the proper curve, to the level of low water, by lowering the water in the basin for 18 hours, and the caisson was dropped into position against these end walls by a 40-ton crane. The two lateral air-tight chambers caused it to float with about 23 feet draught and a slight list to port, and sufficient water was then admitted into the chambers to sink the caisson into place. The working space was subsequently pumped dry, and the external pressure caused the caisson to adhere firmly to the wall of the dock, the junction between the outer skin of the caisson and the end walls being made water-tight by means of wedges of soft wood, rolls of hemp and bags of waste. In fifty minutes from the time the caisson was launched the chamber was ready for the work to start.

G. R. R.

The Improvement of the Emden Harbour Works and the Dortmund-Ems Canal.

(Archiv für Post und Telegraphie, 1900, p. 196.)

One of the matters to be considered by the Prussian Government in 1900 is the development of the harbour at Emden and the deepening of the Dortmund-Ems canal. Considerable discussion has already arisen upon the results already obtained, and this proposal is therefore of interest.

Although the canal is at present only 6·56 feet deep and has been open for traffic only a few months, it has clearly proved its great national importance. Many thought that the traffic would be restricted to coal and iron ores, but it is already far exceeding their expectations. The Hamburg-American line of steamers has now decided to call at the Emden harbour for its goods traffic and to use Westphalian coal as far as possible, and the Westphalian Transport Co. is also making preparations to deal with the traffic. The Government has decided to improve the canal and harbour so that it shall be possible for regular sea-going steamers to come alongside the quays, and for vessels of the German navy also to use the Ems and to lie in the Emden harbour.

It has been agreed that the Hamburg-American line shall rent a certain part of the buildings to be erected by the State in the outer harbour; these include 656 feet length of quays, about 44,000 square feet of goods sheds, and 53,800 square feet of coal sheds, both fitted with electric cranes, railway lines, and other accessories. The total cost of these works will be £65,700; the company will maintain the whole plant at their own cost and will also pay to the Government interest upon the capital outlay at the rate of 3 per cent. for the first 5 years and 3½ per cent. for the next 5 years, but will, however, also pay the usual port dues.

Besides this an agreement has been come to by the Hamburg-American line, the Westphalian Transport Co., the North German Lloyd and others, by which it is proposed to deepen the lower waterway. At present the depth is 28·0 feet, and it is considered necessary to increase it to 32·8 feet at ordinary high water, which is equal to 24 feet at ordinary low water, and 22 feet at low water of spring tides. The cost of this work will be £125,000 for dredging, and the outer harbour at Emden would be made 38 feet deep, so that vessels drawing 26·2 feet could float at low water. The total cost of the whole works is estimated at £394,200, and they must be completed by the spring of 1901. The canal itself is not yet quite finished, as it is now only 6·56 feet deep instead of 8·2 feet. The Author gives details as to the traffic returns, which appear very promising.

E. R. D.

The Port of Bilbao.

(Revista de Obras Publicas, 1900, p. 25.)

Descriptions of works at the Port of Bilbao have appeared in earlier issues of the Revista, but this article describes the progress made during the past two years. In July, August and September of 1898, and in March, April and May, 1899, a length of about 289 yards was added to the superstructure, making about 830 yards in all, measured upon the exterior face of the wall.

Groynes have been built upon the foreshore at Las Arenas, and a sea-wall to protect the high road from Las Arenas to Algorta which had been already damaged by the sea. At Algorta the sea is encroaching, as is clearly proved by a comparison of maps since 1731, and it is essential that the movement of the foreshore should be prevented; unfortunately the construction of the sea-wall in the port and the dredging of the river has increased the scouring of the foreshore. In view of this effect a revised design of works was submitted to the Board of Public Works, and was approved on 24th April, 1899, which would entail an additional outlay of £27,138. This includes the construction of a retaining wall from Las Arenas to Algorta, upon which will be a service road; the total length will be 1,640 yards, and there will be access steps from the foreshore every 109 yards.

The town of Algorta contributes one-third of the cost of works of a similar character, which will cost £10,106, the total length of wall will be 1,260 yards, and the width of the road 7·65 yards, its level being 24·6 feet above low water of spring tides. At the end of last year the whole of this work had been completed except 55 yards.

At the edge of the sea-wall there is a parapet of rough stone work in cement, which is completed already for a length of 850 yards. It was found that during storms the waves broke over the parapet, and it was therefore decided to make the road somewhat further from the edge of the wall than had been originally intended, and these alterations have increased the estimated cost by £3,168.

E. R. D.

Standard Method of Conducting Steam-Boiler Trials.

(Report of the Committee of the American Society of Mechanical Engineers presented at New York, December, 1899.)

The Committee confirms the general principles embodied in the Society Code of 1885, but submits a revised code, termed the Code of 1899, embodying amendments based on the practical

experience gained and on the improvements made in instruments during the interval of 13 years. These amendments relate to the use of improved steam calorimeters, to sampling coal and determining its moisture, to calorific tests and analysis of coal, to analysis of flue gases, to smoke observations, to determination of efficiency and to working out the "heat balance."

The 1885 Code is confirmed to the effect that the "unit of evaporation" should be 1 lb. of water at 212° F. evaporated into dry steam of the same temperature. The capacity of a boiler should be expressed in terms of the "number of lbs. of water evaporated per hour from and at 212°;" but in respect to stationary or land boilers, it is stated to be expedient that the measure of capacity in terms of "boiler horse-power" should also be retained. A "boiler horse-power" is defined as "34½ units of evaporation per hour," and as practically equivalent to "an evaporation of 30 lbs. of water from a feed-water temperature of 100° F. into steam at 70 lbs. gauge pressure."

Quality of Steam.—The moisture in the steam should be determined by either a throttling or a separating steam calorimeter. When the percentage of moisture is irregular or in excess of 3 per cent., the results should be checked by a steam separator placed in the steam-pipe as close to the boiler as convenient, with a calorimeter in the steam-pipe just beyond the outlet from the separator. The results given by the two instruments should be added together.

Sampling and Determining Moisture in Coal.—A representative shovelful should be taken from each barrow-load or fresh portion of coal and kept in a cool place till the end of the trial, when the samples should be mixed and reduced by quartering and crushing until a final sample of about 5 lbs. is obtained, and the size of the larger pieces is such that they will pass through a sieve with ¼-inch meshes. Two one-quart air-tight vessels should be filled from this sample and retained for determinations of moisture and heating value.

For an accurate determination of moisture, one of the samples contained in the air-tight vessels should be taken and thoroughly air-dried to find the quantity of surface moisture contained. Then crush the whole to somewhat coarse grains (less than $\frac{1}{16}$ inch), mix and select portion of 10 grams to 50 grams, weigh and dry in air or sand bath at a temperature between 240° and 280° F. for an hour. Weigh again and record loss; heat and weigh at intervals of an hour or less until minimum weight has been reached and weight begins to increase by oxidation. The average of two samples should be taken, and the difference between the original and minimum weight is the moisture in the air-dry coal, to which must be added the surface moisture to obtain the total moisture in the coal.

Calorific Tests and Analysis of Coal.—The rational method of determining the total heat of combustion is to burn a sample of

coal in an atmosphere of oxygen gas. (Appendixes XIII and XIV deal with several calorimeters and give comparative results attained by several types and by analysis.)

The total heat of combustion computed from the results of the ultimate analysis may be obtained by the use of Dulong's formula (with constants modified by recent determinations) viz.:—

$$14{,}600\ C + 62{,}000\ (H - \frac{O}{8}) + 4{,}000\ S$$

in which C, H, O and S refer to the contained proportions of carbon, hydrogen, oxygen and sulphur respectively.

Analysis of Flue Gases.—The analysis of flue gases is recommended as especially valuable in determining the relative values of different methods of firing or kinds of furnaces. The use of instruments for approximate determinations are dealt with in Appendixes XXXIII and XXXIX.

Smoke Observations.—It is desirable to determine and record the quantity of smoke produced when bituminous coal is used, and to actually measure a sample of soot and smoke by some form of meter. Two methods are described in Appendixes XXXIV and XXXV.

Efficiency.—Two methods of defining and calculating the efficiency of a boiler are recommended:—

$$(1)\ \text{Efficiency of the boiler} = \frac{\text{heat absorbed per lb. combustible.}}{\text{calorific value of 1-lb. combustible.}}$$

$$(2)\ \text{Efficiency of boiler and grate} = \frac{\text{heat absorbed per lb. of coal.}}{\text{calorific value of 1 lb. of coal}}$$

The first of these is recommended as a standard of comparison for all tests, but the second should be included for the purposes of comparing different furnaces, grates, fuels, or methods of firing.

The heat absorbed is to be calculated by multiplying the equivalent evaporation from and at 212° per lb. of combustible (or coal) by 965·7.

The Heat Balance.—When analyses of the fuel and chimney gases have been made, an approximate "heat balance," or statement of the distribution of the heating value of the coal, may be included in the report of the test. It should be in the appended form.

Forty-one Appendixes, giving the views on particular points of individual members of the Committee and others, are annexed to the Report, together with a reprint of the discussions (so far as the suggestions brought forward have not been adopted in the final Report) on the presentation of the drafts and final copy of the Report.

TOTAL HEAT VALUE OF 1 LB. OF COMBUSTIBLE ..... B.T.U.

—	B.T.U.	Per Cent.
1. Heat absorbed by the boiler = evaporation from and at 212° per lb. of combustible × 965·7 . .		
2. Loss due to moisture in coal = per cent. of moisture referred to combustible ÷ 100 × [(212 − t) 8 + 966 + 0·48 (T − 212)]. (t = temperature of air in the boiler-room, T = that of the flue gases) . . .		
3. Loss due to moisture formed by the burning of hydrogen = per cent. of hydrogen to combustible ÷ 100 × 9 × [(212 − t) + 966 + 0·48 (T − 212)]		
4.[1] Loss due to heat carried away in the dry chimney gases = weight of gas per lb. of combustible × 0·24 × (T − t)		
5.[2] Loss due to incomplete combustion of carbon— $= \frac{CO}{CO_2 + CO} \times \frac{\text{per cent. C in combustible}}{100} \times 10{,}150$		
6. Loss due to unconsumed hydrogen and hydro-carbons, to heating the moisture in the air, to radiation, and unaccounted for. (Some of these losses may be separately itemised if data are obtained from which they may be calculated). .		
Totals		100·0

W. B.

New Standard Tests for Steam Boilers and Engines in Germany to supersede those prescribed in 1884.

(Approved of by the Verein deutscher Maschinenbauanstalten and the Verein deutscher Ingenieure, and under consideration by the International Verband der Dampfkessel-Ueberwachungsverein.)

The new Code entirely supersedes that of 1884, and is a complete set of instructions for testing steam-boilers and engines.

It is recommended that the tests of a steam generating plant should include the determination of:—

(*a*) The quantity of steam produced per hour per square metre of heating surface.

[1] The weight of gas per lb. of carbon burned may be calculated from the gas analysis as follows:—

Dry gas per lb. carbon $= \frac{11\,CO_2 + 8\,O + 7\,(CO + N)}{3\,(CO_2 + CO)}$, in which CO_2, CO, O, and N are the percentages by volume of the several gases.

The weight of dry gas per lb. of combustible is found by multiplying the dry gas per lb. of carbon by the percentage of carbon in the combustible, and dividing by 100.

[2] CO_2 and CO are respectively the percentage by volume of carbonic acid and carbonic oxide in the flue gases. The quantity 10,150 = number of heat units generated by burning to carbonic acid 1 lb. of carbon contained in carbonic oxide.

(*b*) The number of kilograms of water at a given temperature, converted into steam at a certain temperature, and pressure by the combustion of one kilogram of fuel.

(*c*) The efficiency, *i.e.*, the proportion of the heat transmitted to the contents of the boiler to the heating value of the fuel.

(*d*) The heat lost and the amount due to each source of loss.

And in the case of a steam-engine plant the determination of:—

(*a*) The indicated and useful work.

(*b*) The mechanical efficiency, *i.e.*, the proportion which the useful work bears to the indicated work.

(*c*) The steam used per HP. per hour.

(*d*) The heating value of the steam used per HP. per hour.

(*e*) The steadiness of running with a varying load.

The number and duration of tests for various purposes is indicated, together with the permissible deviation from guaranteed performances under various circumstances, and instructions as to the weights and measures to be utilized in stating the quantities, such as heat-units, pressure, etc., the methods of measuring heating surface, etc., are given.

The evaporation by one kilogram of fuel, and the evaporation per square metre of heating surface are to be stated as calculated on the basis of water at 0° C., and dry saturated steam at 100° C.

The measure of useful work done by the steam-engine is to be taken as the difference between the work indicated under load, and the power absorbed when running light.

A strictly accurate determination of the useful work is only possible by the use of a brake, but it is recommended that this should only be adopted in exceptional cases, as with powerful engines it involves both difficulty and danger.

When the engine is driving a dynamo, the useful work may be arrived at by electrical measurements.

Very full directions are given for the actual carrying out of the tests and auxiliary work.

Besides the calorimetric determination of the heating value of the fuel the chemical analysis may be utilized by means of the following formula:—

$$8{,}100\ C + 29{,}000\left(H - \frac{O}{8}\right) + 2{,}500\ S - 600\ W.$$

Two appendixes deal with the determination, in a more complete scientific manner, of heat and work lost in the boiler and engine respectively.

The high temperature T at which the gases leave the boiler flues involves the loss of a number of heat-units per kilogram of fuel, which may be found by the following formula, in which *k* is the volume percentage of carbonic acid in the gases, and *t* is the temperature of the atmosphere:—

$$V = \left(0{\cdot}32\ \frac{C}{0{\cdot}536\,k} + 0{\cdot}48\,\frac{9\ H + W}{100}\right)(T - t)$$

A further source of loss is the dropping of unburnt fuel through the fire-bars.

When these losses are expressed as percentages of the calorific value of the fuel, their sum will differ from 100 by the losses due to radiation and conduction of heat, unconsumed gases and soot.

The lost work in the steam-engine may be estimated by calculating the work that would be shown on the indicator diagram were there no losses through clearance spaces in the cylinder, escape of heat through the walls of the cylinder or any deficiency in steam-tightness.

W. B.

Determination of the Value of Fuels for Steam Boilers.

H. BUNTE.

(Zeitschrift des Vereines deutscher Ingenieure, 1900, p. 669.)

In No. 14 of the *Zeitschrift*, p. 460, appeared an article entitled "Data for Determining the Efficiency of Steam-Engines and Boilers," which showed a marked advance on "The Principles and Methods of Testing Steam Boilers" issued in 1884, especially in regard to the proposition: "Can the caloric value of fuel be determined calorimetrically." The present Paper is written to show the practicability of such a method, and to prove it, the Author furnishes a Table giving the results of a series of laboratory experiments on the chemical composition of almost every kind of fuel used in Germany, with the calculated heating power of each according to the formula $81\ C + 290\left(H - \frac{O}{8}\right) + 25\,S - 6\,W$. Where C = percentage of carbon, H that of hydrogen, O of oxygen, S of sulphur, and W of moisture. These calculated values approximate so closely to the values of the same fuels determined by calorimetric experiments made in the furnace, that the Author strongly commends systematic observations being made in every engine-room. The method and principles on which these experiments may be conducted the Author lays down in this Paper, giving several Tables comparing results. The Author further refers the reader to several articles on the subject which have from time to time since 1879 appeared in the *Bayerishes Industrie- und Gewerbeblatt*, and to one in *Engineering* for February, 1900, p. 271.

W. A. B.

Apparatus for the Inspection of Boiler-Tubes. SECRÉTAN.

(Bulletin de la Société d'Encouragement pour l'Industrie Nationale, April, 1900, p. 527.)

An account is given of an apparatus, the invention of the Author and Mr. Vinsonneau, for the examination of boiler-tubes. By reference to diagrams the construction and use of the apparatus is explained. It consists of a tube fixed at right angles in a chamber provided with a magnifying eye-piece. At the further end of the inspection tube, which is capable of being drawn out to suit the length of the boiler-tube under examination, is an incandescent electric lamp, and an angular plane reflector which transmits the rays to a reflector inclined at a similar angle under the eye-piece. The tube in process of inspection is fixed in a travelling carrier, which permits every part of it to be examined in turn. The carrier is provided for this purpose with both a horizontal and a rotary movement. The present apparatus is designed for tubes of 6·56 feet in length by 1½ inch in diameter, but the same principle can be applied to tubes of larger size and greater length. An apparatus for use in the case of tubes *in situ* has also been devised, and, by reference to a diagram, a method of employing the apparatus for the examination of the exterior surfaces of tubes is explained. It is stated that this invention has proved very satisfactory in use, and that it has often revealed defects in the interior of tubes which externally presented every appearance of soundness.

G. R. R.

Motors and Motor Carriages at the Berlin Exhibition, 1899.

(Zeitschrift des Vereins deutscher Ingenieure, 1900, p. 13 *et seq.*)

The exhibits comprised seven classes, motor-cars, wagons, cycles and tricycles, motors and accumulators, frames and wheels, fittings, and designs and models.

The Author, taking each in order, describes the construction, gearing, and novelties about each, illustrating his Paper with numerous drawings and sections.

In the first class is a Victoria, by the Kuhlstein factory at Charlottenberg; weight of battery 500 kilograms with a working capacity of 5 hours, equal to a journey of 50 kilometres at 10 kilometres per hour; also a carriage from the Marienfelde works after a design by the Columbia Motor Companies of Hartford, Connecticut; with a full load it weighs 700 kilograms, the battery 250 kilograms, the speed 28 kilometres per hour, distance 60 kilometres.

Two electrical carriages, by Henschel of Berlin, with flexible driving shaft, and an electrical launch on the same principle.

Two electrical carriages by the Vereinigten Elektrizitäts Company of Vienna, with single motors and differential gearing, the accumulators supplying power sufficient for a journey of 80 kilometres at a speed of 85 kilometres.

An omnibus by Siemens and Halske, weight empty 6,500 kilograms, 200-cell battery, four 4-HP. motors, besides another carriage, a mail coach, and a parcel van, all by the same firm. In the third class is an electrical cycle by A. Kruger of Berlin, after Müller's patent, besides various bi- and tri-cycles, from the earliest by Daimler down to the most recent productions by Cudell & Co. of Aix-la-Chapelle and other manufacturers.

In the fourth class the examples described are—two Loutzky motors built by the Automobile Carriage Factory, Berlin, a postal van, a four-seated carriage from the "Falke" factory, and one by the Daimler Motor Company of Cannstadt, weighing 1,550 kilograms when fully loaded. A three-seated, and a six-seated motor, besides trollies by the Daimler Construction Company. The exhibits of the Swiss Motor-Carriage Company in Witzikon are notable for the many novel and well-designed accessories; so too are those by Berry & Co. of Mannheim, the latter though cumbersome in appearance, possess a large storage capacity and are able to run 5,000 kilometres without recharging.

Under Benz motors there are a number of the Benz type, viz., a post-cart, a closed and an open cab, an omnibus, and a parcels-van.

Dietrich & Co. of Niederbroon, in Alsace, exhibit a variety of motor carriages; the firm of Pieper a combination of Burin-Benz motor with an electro-motor and also an accumulator. All the above-mentioned exhibits are fully described and illustrated by numerous drawings, this Paper affording comprehensive information regarding the present condition of the motor-car industry on the Continent.

W. A. B.

Valentin Purrey's Steam Omnibus. H. Brosselin.

(Revue générale des Chemins de fer, 1900, p. 77.)

The Lamm and Francq, the Rowan and the Serpollet systems, are the only three survivors of the numerous descriptions of steam omnibuses employed from time to time on the Paris lines.

In 1897 the Paris General Omnibus Company called for tenders for the supply of a steam-driven omnibus, with handy low-pressure boiler capable of being worked intermittently, producing under normal conditions 330 lbs. of steam, and capable of increasing to 882 lbs. for one quarter of an hour. The fuel to be gas with Bunsen burner, coke with automatic stoker or mineral oil.

Mr. Valentin Purrey's omnibus fulfilled these conditions to the satisfaction of the company, six experimental omnibuses were

ordered provisionally, these proving satisfactory, thirty-four more were supplied the year following.

The generator consists of two steam chambers one above the other, connected on one side by two 1·38-inch tubes protected from the action of the fire, and on the other side by a nest of thirty evaporating and eleven superheating tubes. The furnace is made of boiler-plates with fire-brick lining. The fuel is coke supplied by an automatic stoker and lasts for a journey of from 12½ to 15½ miles. There is an automatic and a small donkey pump; the water-tanks are placed below the seats, and the machinery between the axles in the centre of the frame; it is of the simplest possible construction. There are two driving-chains for the front, and two for the hinder axle. The omnibus seats forty-eight, twenty inside, twenty-four outside, and four on the platform; empty, its weight is 9,240 kilograms = 9 tons; full, 12,620 kilograms = 12·4 tons.

The advantages of this system are: lightness of vehicle, absence of noise and smell, or delay in recharging, besides economy in first cost and in maintenance of both permanent way and rolling stock. So satisfactory has the working been that forty new steam omnibuses have been ordered for two more lines in Paris.

The Paper is fully illustrated.

W. A. B.

The Mineral Industry of Bosnia-Herzegovina. T. Poed.

(Paper presented to the International Congress of Mines and Metallurgy, Paris, June, 1900.)

This is an official description of the mineral section of the Bosnia-Herzegovina exhibit at Paris, containing notices of the working of salt, coal, petroleum, iron and other metals—the most important of these being the coal and iron. Although Bosnian iron has been in high repute from a very remote period, the development of this industry only dates from the Austro-Hungarian occupation of the country in 1878, since which time large collieries and ironworks have been brought into a very flourishing condition. The coals, which are black lignites of tertiary age, are worked at two principal centres—namely, Zenica near Sarajevo, and Kreka near Tuzla. At the former place there are three seams; the principal one, a seam 10 metres thick with 7 metres of clean coal, has been worked by a dip slope to a depth of 200 metres, the production of the country, which in 1880 was 500 tons, having increased to 303,425 tons in 1899, while the selling price has been reduced from 11 francs to 4·41 francs per ton. The evaporative power is 5,119 calories, or about two-thirds that of carboniferous coal with 6·5 per cent. ash and 2·48 per cent. sulphur. The low price has been attended with

a somewhat considerable export to Italian and other Adriatic ports, from Metkovic in Dalmatia.

The Kreka coal, which is of a lower evaporative value (4,179 calories), is cleaner than that of Zenica, containing only 0·33 per cent. of sulphur. The seam, 16 metres thick, has been extensively quarried, and in 1899 produced 177,546 tons, which was principally consumed by salt and other works and railways in the district. The production at Zenica for the same year was 125,430 tons. The iron ore resources of Bosnia are very considerable, the most important mines being those of Vares near Sarajevo, where a series of alternations of red and brown manganiferous hematites and spathic ores, included between old crystalline schists and Triassic limestones, are worked in open casts. The deposits measure from 60 metres to 100 metres across, and are estimated to yield 10,000,000 tons of ore without subterranean mining. The ore broken in the workings is lowered by an inclined plane 700 metres long with a fall of 250 metres to the smelting works. The output for 1900 will be about 130,000 tons, about 50,000 tons being exported partly through Metkovic to the Trieste blast furnaces, and partly by the northern railways to works in Hungary and Austria, while the remainder supplies the local furnaces.

Bosnia is the last European country in which the high bloomery furnace has survived. Formerly there were forty of these furnaces at Vares, but now only a single one survives at Stari Majdau in the north-western corner of the country. The typical bloomery contained a blast furnace built of stone and clay with wooden backstaves and binders about 16 feet high and 3½ feet in diameter, blown by two twyers, each having its own bellows driven by an overshot water-wheel and a small forge fire, also with a water-driven bellows. The furnace was filled with alternating layers of small ore and charcoal, and kept in blast for three days. The yield was about 3 tons of iron recovered partly as cast iron which ran out with the slag and partly as a low carburized bloom which was dug out of the hearth and reheated in the small fire and forged to a finished bar under a tilt-hammer. The new Vares works, situated at the foot of the incline bringing down the ore, includes numerous kilns for roasting spathic and brown ores, two blast furnaces with five Cowper stoves, and a foundry for pipes and other castings. The new blast furnace, which is probably the largest charcoal furnace in Europe, is 53 feet high, 15 feet wide in the boshes and 8 feet in the hearth, with six 4½-inch tuyers, with blast at 5 lbs. pressure heated to 700° to 800° C. The charge is 190 lbs. ore, 15 lbs. limestone, and 85 lbs. charcoal per 100 lbs. of pig metal, and the make from 80 tons to 100 tons per day, the composition varying within the following limits:—

	White.	Grey.
Silicon	0·4 – 0·8	1·8 – 3·55
Manganese	3·5 – 6·0	0·9 – 2·20
Sulphur	0·04 – 0·055	0·04
Phosphorus	0·10 – 0 25	0·20
Copper	0·10 – 0·20	0·07

The total production of the year is 40,000 tons, about three quarters being white and one quarter grey metal. Lately a cargo of this iron has been sent to Rotterdam. H. B.

The Coal Industry of the Black Sea Basin.

(Morskoi Sbornik, May, 1900, p. 151.)

Numerous statistical Tables are given to illustrate the condition of the coal, iron and other industries in South Russia. In the last two years prices of coals have gone up very much; at the mines from 8*s.* 3*d.* per ton to 13*s.* per ton for ordinary coals, and from 11*s.* per ton to 18*s.* per ton for anthracite, whilst at Odessa the prices have risen from 20*s.* 6*d.* per ton to 33*s.* per ton for ordinary Donetz coals, and from 37*s.* 9*d.* per ton to 40*s.* per ton for Cardiff coals, which includes 8*s.* 3*d.* per ton duty. The duty on foreign coals was reduced to 2*s.* per ton in 1899, and still the prices have kept inordinately high, thereby greatly hindering the development of most industries in the district. The principal cause of these high prices is that the output of coals does not increase as fast as the demand. It was 3,060,000 tons in 1889, and rose to 7,450,000 tons in 1898, whereas, taking the metallurgical works only, the production of cast-iron was 87,620 tons, and of wrought-iron and steel 55,000 tons in 1888, and in 1898 it was 990,000 tons of cast-iron and 637,000 tons of wrought-iron and steel. In the South Russian works 1 ton of cast-iron is, generally, produced by 1·15 ton of coke or 1·92 ton of coals; and it takes 1·5 ton of coals to produce 1 ton of wrought-iron or steel from cast-iron. The consumption of coals in the southern metallurgical works rose in the last 11 years from 250,000 tons a year to 2,852,000 tons a year, or 1,040 per cent., whereas the Donetz coal output rose only 238 per cent. In 4 years, ending September, 1899, the coal consumption increased :—

	Per Cent.
For metallurgical works	122·4
„ private or domestic use	63·6
„ steamboats	45·9
„ railways	43·3
„ sugar factories	40·0
„ gas works	7·7

The rapid development of the iron industry may be judged from the fact that there were thirty-four blast furnaces at work last year, producing 1,242,000 tons of cast-iron, and this year there are forty-seven at work, which will probably produce 1,700,000 tons of cast-iron. It is estimated the demand for coals in 1900 will exceed the output of the Donetz mine by 450,000 tons. The supply of coals for the Black Sea requirements is also very deficient. The output of the Donetz coal-mines ought to be greatly increased. C. H. M.

Pyrites Deposits on the Proposed Sell and Støren Railway.

E. GULLIKSEN and I. H. L. VOGT.

(Teknisk Ugeblad, Christiania, 1899, p. 427 *et seq.*)

This line will open up a number of pyrites deposits in the western part of the old mining district south of Trondhjem Fiord. The eastern part is already traversed by the railway running south from Trondhjem to Røros and Christiania. Starting from Støren, about 28 miles south of Trondhjem on the Røros line, the new railway will run *viâ* Undal, Opdal, Vaarsti, and Dovre, to Sell, about 115 miles south-west by south of Trondhjem in a straight line. The three most important of the pyrites deposits which will thus be served are those at Undal, Vaarsti, and Foldal, distant by road from Trondhjem respectively about 88 and 155 and 180 kilometres (55 and 96 and 112 miles). The ore is sulphide of iron or yellow mundic, containing from 39 to 48 per cent. of sulphur, with copper from 4½ per cent. down to nothing, and occasional traces of zinc; it is practically free from arsenic. The cost of mining and dressing is from 4 to 5 kroner per ton (4*s.* 6*d.* to 5*s.* 7*d.*). The poorest stuff has to be washed at a cost of about 3 kroner (3*s.* 4*d.*) per ton, which is included in the above. The washing yields 60 to 70 per cent. of clean pyrites. At Undal mine the lode underlies 45° east, and varies in width from 3 to 24 feet in the length thus far opened on; it will yield from 18 to 21 tons of pyrites per cubic fathom, and the yearly output is estimated at 20,000 tons. At Vaarsti there is a north and south flat lode underlying 10° to 30° east, and 6½ to 8 feet wide. At Foldal is the largest single deposit hitherto met with in the country, containing also the greatest thickness of pyrites in the width of the lode; the ore ground at present discovered amounts to 874,000 tons, besides 300,000 tons already taken away; the yearly output is estimated at 37,500 tons. The existing railway rates range from 0·43*d.* to 0·56*d.* per ton-mile. From the beginning of the sixties, when the yearly supply of pyrites from Norway amounted to about 50,000 tons, it had risen in 1898 to 90,000 tons.

A. B.

Improvements in Shaft-Sinking. P. SIMONS.

(Schweizerische Bauzeitung, 1900, p. 65. Figs.)

The municipal theatre at Berne is now being built, and the structure rests partly upon columns for which shafts were sunk by a special system. The site lies along the upper slope of the left bank of the Aar river near the end of the Kornhaus bridge. The natural bottom consists of gravel sand and loam of irregular formation, but above this is made ground to a depth of 26 feet to

33 feet on the east front, and from 33 feet to 49 feet on the west front. When the Kornhaus bridge was built it was decided that this moraine ground should not be loaded to a greater extent than from 2 tons to 3 tons per square foot. The Author suggested that the footings should be carried upon solid columns which should pass down through the made ground into the natural formation. The sinking of the shafts was effected as follows:—A hole was dug about 3 feet deep, and of the desired section, which was chosen rectangular. A solid wooden frame was then fixed at the bottom to form the bottom of the lining, and to this were fixed stout boards to act as an inner shell; the space between the shell and the excavation was then filled with concrete, in which bent iron rods were inserted in a horizontal direction at short intervals. As soon as the concrete had set the bottom of the pit was excavated, the ring and shell lowered and again filled with concrete, each ring of concrete being bonded to the rest by iron joggles; the top and bottom of each ring were chamfered so as to leave a V shaped groove inside. When the natural formation was reached, bars were fixed in a slanting direction to support the soil, and the bottom of the shaft was enlarged and undercut. The whole shaft was then filled in solid with concrete up to the top, the core being keyed to the skin by means of the horizontal V grooves. The adjoining columns were tied together at the top by horizontal concrete beams into which were embedded steel joists, and the walls were built upon the concrete beams. Altogether nine single columns and two double columns were built, the cross sections varied from 6·6 feet by 6·6 feet to 10·8 feet by 15 feet, and the depths from 21·3 feet to 33 feet.

E. R. D.

The Dulait-Forget Electric Rock Drill. CUVELLETTE.

(Bulletin de la Société de l'Industrie Minerale, vol. xiv., December 3, 1900, p. 161.)

This is a percussive drill driven by an electro-motor, the percussive action being obtained by the release of a coiled spring which is compressed by a cam attached to a fly-wheel rotating in a horizontal plane. The electro-motor is mounted on a movable carriage and connected with the fly-wheel of the drill by a Marotte flexible shaft and bevel gearing, giving a change of speed of about 3 to 1 or 420 revolutions of the drill cam to 1,300 of the motor per minute. Motors of different kinds have been used, the principal trials having been made with one of 1½ HP. taking a continuous current of 14 amperes at 110 volts with a yield at full load of 78¼ per cent., or 1·65 HP. The drill springs are of variable stiffness, requiring pressures of 60, 80, 100 or 120 kilograms, for a compression of 7 centimetres, the length of the working stroke. Stronger springs of square section, requiring 140 kilograms pressure, have been tried without any great advantage. The

work of compression represents about 4½ kilogrammetres per stroke, or, at a speed of 420 strokes per minute, 31½ kilogrammetres per second. As the motor absorbs 7 amperes at 220 volts, giving 123 kilogrammetres, the useful effect is about 25 per cent. or 20 per cent., taking into account the losses between the motor and primary dynamo. Under similar conditions an Eclipse drill No. 5, worked by compressed air, gives a little less than 30 per cent. Subsequently a more powerful drill, known as No. 3, has been adopted, giving three times the effect for little more than double the power, which is supplied by a continuous-current motor of 3½ HP., taking 30 amperes at 110 volts, with a yield of 80·25 per cent. This drill has been used at the Flaviac mines in driving a cross cut 2·25 metres square, and 1,350 metres long, through rocks of variable hardness, including siliceous marls of the Oxford clay, mica schist and granite. The plant, including a primary dynamo of 11 kilowatts, switchboard conductors, cables and insulators, three rock drills with stands, motors and carriages, cost about 10,000 francs. The cost of insulated cables, amounting to 2·50 francs per metre, is nearly that of a compressed air conduit of equal capacity. The drills are non-automatic, the blows being struck continuously in the same plane, the rotation and forward feed of the tool being effected by hand. The cost and rate of driving per week in the different classes of rocks have been as follows:—

—	23–29 August, 1897. Siliceous Marl.		9–15 May, 1898. Mica Schist.		12–18 December, 1898. ½ Mica Schist, ½ Granite.	
		Francs.		Francs.		Francs.
Coal . . .	4·8 tons at 31·75 francs	152·40	5·46 tons at 30 francs	163·80	6·36 tons at 30 francs	190·80
Lubricants . .	..	4·20	..	6·50	..	8·00
Number of shots fired . . .	..	162	..	114	..	130
Dynamite . .	126·8 kilograms	Francs. 433·70	96·5 kilograms	Francs. 308·80	114·5 kilograms	Francs. 366·40
Caps and fuses	..	29·00	..	14·85	..	18·20
Wages, firemen, &c. . .	..	49·00	..	94·50	..	160·85
Wages, miners	..	292·25	..	360·75	..	431·75
	Total	960·55	..	949·20	..	1,176·00
Length driven	..	11·50 metres	..	8·40 metres	..	12·20 metres
Cost per metre	..	83·52 francs	..	116 francs	..	96·40 francs

For some time the progress realized with the No. 2 drill was 1·35 metre per day, while in similar ground with a slightly small section of the gallery only 0·35 to 0·4 metre could be done by hand work.

H. B.

The Use of Concrete in Mines. MARCEL HABETS.

(Revue universelle des Mines, 1900, p. 35.)

At the collieries belonging to the John Cockerill Company at Seraing, concrete has been extensively employed for securing underground works, both in shafts and levels, instead of brickwork. The most important of these applications has been in the refitting of a shaft 4½ metres in diameter originally secured with wrought iron rings and struts with a lining of planks and subsequently lined with brickwork, and parts where the metallic lining proved insufficient; but as neither system proved sufficiently stable, it was decided to substitute a concrete lining 500 millimetres thick. For this purpose the shaft was enlarged to 5½ metres diameter in lengths or passes of 10 to 20 metres, according to the nature of the ground, and temporarily secured by channel-iron rings supported from the lowest ring above the pass. For the new lining a ring of 4½ metres diameter, made of ⊏ iron 200 by 20 millimetres in the web, and 100 by 12 millimetres in the flanges, is carefully levelled and centred at the bottom, and twelve vertical wooden props 600 millimetres high are placed to support the next ring above. Sheet-iron plates forming the inner mould for the lining are attached to the props by wood screws, and the concrete prepared at the surface is then poured in and carefully rammed to drive out the air and completely fill the space up to the rock behind. The inner side of the lining is brought flush with the flanges of the rings, so that the latter are completely fixed in the concrete. The cost of the concrete fixed in place was 15 francs per cubic metre. These linings have now stood without any change for one year in places where previously continual repairs were necessary. The same material has also been applied on the lining of an underground pumping-engine chamber 4½ metres in diameter. This was made by driving a heading in the upper part enlarging to the full size, and filling the concrete over a mould carried by semicircular centerings, which were subsequently reversed and used for the invert of the arch. This being easier work than the shaft lining was done at a cheaper rate, or 10·70 francs per cubic metre. A third application is in the construction of a dam in a level to resist a pressure of 16 atmospheres. This is a truncated pyramid of concrete 5 inches thick, the pressure being received on a brick wall at the broad end. Slow and careful ramming was necessary to ensure the complete filling of the cavities in the rock so as to get a perfectly watertight junction. The water was admitted to the face of the dam three weeks after the work was finished, when the pressure rose to 8 atmospheres and has continued stationary ever since, without any signs of filtration or passage of water through the body of the concrete or between it and the rock. The cost was 12 francs per cubic metre.

The most special application has, however, been in the formation of a drift uniting an upcast air-shaft with the intake of a

Mortier fan. This is horizontal and circular in section, 3 metres in diameter at one end, and rectangular with an inclination of 45 degrees at the other. This was easily and quickly done, the necessary change of section being obtained by appropriate templates at half-metre intervals, while it would have been almost impossible to carry it out in brickwork.

The concrete used in the works has been made entirely from blast furnace slags, those from forge-iron broken to 30 or 50 millimetres being used as ballast, while the mortar is made of granulated slags, hydraulic lime in the proportion of 5 to 1 by volume and slag cement. These are incorporated in a mortar-mill, but no addition of water is necessary, as the granulated slag contains enough. Slag cement is made of about 75 per cent. of granulated grey iron slags and 25 per cent. of slacked lime. When the slags are tolerably uniform in character chemical analysis of the materials is not necessary except when the furnace charges contain magnesia, which should not be present to a greater extent than 3 per cent.

The materials required for a cubic metre of concrete are—

0·750 cubic metre granulated slag.
0·150 „ „ hydraulic lime.

This is reduced in volume by mixing about one-half, giving—

	Cubic Metre.
Slag and lime mixed	0·450
Cement, 100 kilograms	0·100
Broken slag	0·800

This when carefully rammed gives one cubic metre of concrete in place. Models of these works have been sent to the Paris Exhibition. They are in the gallery of the Belgian section of the group of Mining and Metallurgy.

H. B.

The Use of Electricity in Mines. I. LIBERT.

(Bulletin de la Société de l'Industrie Minerale, vol. xiv. p. 87.)

This is one of the Reports presented to the International Congress of Mines and Metallurgy at Paris, and contains summary notices of all the different applications of electricity to mining machinery that have been made in Belgium up to the present time. These, apart from surface and other lighting plants, include fourteen hoisting engines, ten underground pumping-engines, three haulage lines, one of them employing secondary battery locomotives on a line of about a mile in length, and one ventilating fan. Electric rock-drills have also been applied, but not beyond an experimental scale. In the larger number of cases continuous current at 500 to 650 volts is used, but in the district east of Liége triphase alternators have been adopted, at about the same

tension in the first applications, but in newer installations now erecting this has been increased to 2,000 volts. One of the most interesting applications described is that at No. 8 pit Courcelles-Nord collieries, where an outlying portion of a seam containing about half a million tons of coal has been won by a pit 125 metres deep sunk at the end of the 376 metres level at a point 1,100 metres distant from the shaft bottom. This is equipped with a hoisting-engine with spiral rope drums of 60 HP. effective at the bottom with a pumping-engine of 25 HP. effective at the top. The generating station at the surface contains two 100 HP. condensing-engines with two Babcock and Wilcox boilers, and two primary dynamos of a capacity of 65 kilowatts, or about 88 HP. each when making 600 revolutions per minute, the tension varying from 540 to 620 volts. The total length of the circuits is 3,800 metres to the hoisting, and 4,060 metres to the pumping-engine, the copper conductors of the insulated cables having a section of 95·19 millimetres, equal to a cylinder of 11 millimetres diameter. By this arrangement the necessity of increasing the depth and refitting of a large shaft in bad ground and the driving a new stone road 1,100 metres long has been avoided. At the Strepy Bracquenie colliery, near Mons, Sussman's portable glow-lamps have been entirely, and in some other mines partially, substituted for safety lamps, about 2,000 of them being now in use. This has a dry cell secondary battery, the electrolyte dilute sulphuric acid being absorbed by small scraps of filter-paper giving a stiff adhesive mass; the active matter employed for forming the accumulator plate is finely powdered litharge mixed with a weak solution of india rubber and formed to a paste with ammonium sulphate; each element contains two negative and one positive plate, the former weighing 175 grams, and the latter 230 grams each; two elements coupled in tension are used with each lamp. The charging of the accumulators with a current of 0·7 ampere and 5 volts requires 11 hours, and in attaching the lamp to the cell it is arranged that contact need not be made until the light is actually required, which gives an average saving of about $\frac{3}{4}$ hour's light in each shift. The lamps are supplied by the Dry Accumulator Company of Belgium at a rent of 2·25 francs per lamp per month; the cost of the energy consumed is below 10*s*., and of labour in filling, cleaning, etc., about 16*s*. per thousand lamps per day.

These figures, on the basis of 25 working days per month, give a total cost per lamp of 11·7 centimes (about $1\frac{1}{8}$*d*.) per day of 11 hours. In spite of its great weight this lamp is very popular with the miners, as it gives about $2\frac{1}{2}$ times the light of a Museler safety lamp. A reserve of charged lamps of about 6 per cent. is required underground to provide for those becoming injured or inactive through exhaustion of the accumulator during the shift.

H. B.

On a New Form of Blast Furnace Construction. F. BÜRGERS.

(Stahl und Eisen, July 1900, p. 675.)

This Paper describes a new development in the construction of blast furnaces by the substitution of a heavy cast-iron structure for the ordinary thick firebrick wall in the boshes and the lower part of the stack. This has been applied in a new furnace at the Vulkan works, Duisburg, about 60 feet high, 19 feet wide in the boshes, 9 feet in the hearth and 13 feet at the throat. The lower part of the furnace is built of firebrick up to about 4 feet above the tuyers where the bosh wall begins. This is made of segmental cast-iron plates, shaped to the sweep of the furnace, built up in rings connected together by external flanges and bolts like a pit tubbing. The plates are about 2 inches thick, with projecting interior ribs of about the same thickness, which are filled up with firebrick to a smooth surface. At the back there are radial projecting ribs, notched in the middle to form the seat for the binding hoop. Each ring is from 4 feet to 5 feet high, and the upper surface of the bottom flange is furrowed to form a channel for the cooling water, which is kept constantly flowing over the outside. There are three rings in the bosh wall and five in the low part of the stack, so that the iron construction covers about one-half the height of the furnace; the remaining portion of the stack up to the throat is in 20-inch brickwork without a casing wall. The furnace has been at work for nearly a year making Bessemer pig with 2½ per cent. to 3 per cent. of silicon at the rate of 85 tons daily, the coke consumption being about 5 per cent. more than that of an adjoining furnace of the ordinary construction doing similar work. The output is low owing to deficient blowing power, but the furnace works with great regularity. The cooling water required is 0·75 cubic metre per minute, or 6 litres per square metre of surface, the rise in temperature being about 20° C. In further illustration of the principle, the Author gives diagrams and a Table of the weights of materials required for the construction of a furnace like that at Youngstown, Ohio, making 600 tons daily, in brick and iron work respectively.

	Vulkan Furnace.	600-ton Furnace.	
	Iron.	Brick.	Iron.
Capacity . . .	300 cub. m.	800 cub. m.	800 cub. m.
Cast iron . . .	160 tons	..	420 tons.
Bolts	2	..	7
Binders . . .	10 tons	..	18 tons.
Casing . . .	..	70 tons	10 „
Brickwork . .	100 „	1,500 „	130 „
Total weight .	270 „	1,570 „	585 „
Weight per metre in height . .	19 „	67 „	25 „
Cooling surface .	152 square metres	150 cooling blocks	460 square metres.
Cooling water per minute . . .	0·75 cubic metre	6 cubic metres	3 cubic metres.

H. B.

Iron-Nickel Alloys. Rudeloff.

(Verhandlungen des Vereins zur Beförderung des Gewerbefleisses, Sitzungsbericht, 1900, p. 38.)

The subject of this Paper is the work of the Committee on iron-nickel alloys appointed by the "Verein zur Beförderung des Gewerbefleisses."

In the preparation of the alloys magnesium was added to the bath with a view to prevent the formation of cavities in the resulting ingot. The proportion was 42 grams magnesium to 30 kilograms nickel. The result, however, was not very successful, neither was the addition of manganese of much effect.

The physical investigations showed (*a*) that the coefficient of expansion with heat was very nearly the same for all the pieces cast or subsequently worked; (*b*) that the electric conductivity of the cast metal was not altered when it was afterwards hammered or rolled.

The results of the tests for strength showed that with cast metal the nickel containing manganese furnished a greater ultimate strength and extension than the nickel with no manganese.

By the operation of working or forging, however, while the strength and ductility was increased for both kinds of alloy, that free from manganese had the greatest increase, so that finally its absolute strength was practically the same as that of the alloy containing manganese.

On the basis of the above results alloys containing no manganese were used in all the subsequent experiments, and from the experience gained in the preparation of the ingots, it was found that the best results were obtained by adding in the case of alloys rich in iron 20 grammes of aluminium, and with alloys rich in nickel 10 grammes of mangnesium, in both cases to 20 kilogrammes of the material.[1]

Another series of alloys has now been prepared with a view to determine the effect of carbon on nickel alloys. The investigations are not yet complete, but the Author gives a full account of the constituents and preparation of the alloys whose properties are to be determined. A few of the results already obtained are mentioned.

The fine-grained structure of nickel free iron being transformed by the addition of carbon into a radiated crystalline appearance, the addition of 3 per cent. of nickel caused the carbon to separate out in the form of graphite.

When the carbon remained constant and the quantity of nickel was varied from 0·3 to 60 per cent., the following was the result:—

Up to 0·3 to 0·5 per cent. carbon the pure iron showed the lowest, and the 3 per cent. nickel the highest elastic limit and yield point, while the tensile strength and shearing strength were greatest for the alloy containing 60 per cent. nickel. When the carbon was greater than 0·5 per cent., the 3 per cent. nickel alloy was superior in all points to the 60 per cent. alloy. W. B.

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[1] Verhandlungen des Vereins, 1896, p. 65, and 1898, p. 327.

Measurement of Sailing Yachts.[1] H. C. Vogt.

(Ingeniøren, Copenhagen, 1899, pp. 333–336.)

The rules in general use for the measurement of sailing yachts are in the Author's opinion defective and misleading; and he explains at considerable length his reasons for arriving at this conclusion. What is wanted is some rational mode of obtaining a direct measurement of the vessel's efficiency, excluding tentative building, and promoting such designs as shall best utilize the driving power of the wind. A formula for this purpose must therefore be limited to the ratio which the yacht's ability to appropriate wind-power bears to its ability to convert this power into useful work in driving its own weight through the water at the highest possible speed, as in sailing matches. The first term of this ratio involves the boat's stability, which for any angle of keel is represented by the displacement multiplied by the distance between two vertical lines drawn through the centre of gravity and the metacentre; the product is accordingly of four dimensions. Hence two vessels of similar design can be compared by raising to the fourth power any corresponding dimension in each. But in dissimilar designs the most correct representative of the stability is the sail area squared; and this represents also the ability of the sails to appropriate wind-power, because the wind-pressure upon the sails, which depends on the stability, represents potential energy. For the other term of the ratio, the vessel's resistance is a function of its weight, form, and surface; the two latter determine the vessel's merit, and qualify its ability to drive its weight forwards. As the weight is represented by the displacement, the Author's formula for measuring the yacht's efficiency becomes in its simplest form $q S^2 \div D$ = sail-length, where D is the displacement in cubic feet, S the sail area in square feet, and q a coefficient, say about 0·01. The quotient is the length of sail in feet, which constitutes the measurement whereby the yacht is classified. Rig and sail are the most prominently important considerations, representing for a yacht both the engine-power and the propeller of a steamer. Replacing S by $(S_n + g\,S)$,[2] the Author shows the advantages of the modified formula $q\,(S_n + g\,S)^2 \div D$ = sail-length, where S_n represents the normal sail-area generally adopted from experience of the most successful yachts, and $g\,S$ is the additional sail-area in excess of the normal; the coefficient g depends upon the judgment of the yacht's designer, and is less than unity. It is upon the relation which this additional sail-area $g\,S$ bears to the vessel's weight that he considers the success of a racing yacht mainly depends. A. B.

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[1] See also *Engineering*, 1900, April 13, p. 472, and April 27, p. 559, and May 4, p. 593.

[2] Presumably the Author must have meant to write $g\,S_n$ instead of $g\,S$, wherever this term occurs.—A. B.

The First German Cable-Steamer.

(Archiv für Post und Telegraphie, 1900, p. 49. Plan.)

Out of the 42 cable-steamers in the world Great Britain possesses 34, and until recently Germany had none, although she has about 2,331 miles of submarine cable. For all cable work Germany hired British vessels, but as soon as it was decided to lay a cable from Germany to the United States, the North German Submarine Cable Company of Cologne, which put down cable works at Nordenham, also considered the building of a special vessel.

This vessel was ordered from David J. Dunlop of Glasgow, and has been named "von Podbielski" after the secretary to the post-office. The steamer is built according to the rules of the German Lloyd, her length between perpendiculars is 255 feet, greatest breadth 35 feet. She is intended for 1,300 tons burthen, and when fully loaded draws 16·4 feet of water. She is rigged as a schooner with 2 masts.

A plan of the vessel is given, and the various arrangements are described.

The cable is stored in three tanks, one forward 26 feet diameter and 10·8 feet deep, one amidships 31·5 feet diameter by 10·2 feet deep, and one aft 28·0 feet diameter by 12·0 feet deep. Each has a cone in the centre built of plate. The three tanks together have a capacity of about 20,700 cubic feet. There are water ballast tanks capable of holding 300 tons of water. The engines are of the triple expansion type with surface condensation, the cylinders are respectively 16·9 inches, 28·5 inches, and 47·0 inches diameter, with a stroke of 33 inches. The vessel attains a speed of 13 knots with a load of 500 tons, and she has twin screws.

Winding engines are provided both fore and aft. This vessel is intended for the laying of new cables and maintenance of existing cables in the North Sea and the Baltic, but it is not suitable for work upon the Atlantic cable, for which purpose the same cable company are about to order another vessel of 6,000 tons to 8,000 tons burthen.

E. R. D.

Improvement of the German Direct Mail Service with Africa.

(Archiv für Post und Telegraphie, 1900, p. 389.)

The German authorities expect a great increase in the volume of trade with South Africa immediately on the conclusion of the Transvaal war and the pacification of the district, and they are preparing to assist German enterprise in every possible way.

The article in question gives the draft of a Bill which is expected to become law on the 1st April, 1901, and will offer greatly increased facilities to German trade.

The Government is authorized to subsidize a mail steamer service to Africa which would give a 14-day service to East Africa, and a monthly service to South Africa for a period of 15 years, the subsidy not to exceed £67,500 per annum. The services would consist of a principal line going from east to west, and *vice versa* along the coast of Africa, and a subsidiary line going through the Suez Canal to East Africa. The speed of the vessels on the western journey, and also upon the portion between Naples and Dar-es-Salaam on the eastern journey must be 12 knots, and upon the other portions 10½ knots, while upon the subsidiary line the speed is to be 10 knots.

The existing line of Royal German mail steamers to East Africa, which will be greatly improved by the act referred to, is already far superior to what it was formerly. The subsidy as arranged in March, 1890, was given to a line of steamers running at intervals of 4 weeks between Hamburg and Zanzibar, the chief places on the German Protectorate and Delagoa Bay; besides this there was a coast service to the Portuguese possessions. In 1892 the chief line was extended to Durban, and was run in connection with steamers of the German East African Company from Bombay to Zanzibar. Since 1896 the service has been every 3 weeks, and since 1898 every fortnight. The increase in goods traffic has been very considerable, amounting, exclusive of noble metals and specie, to 21,651 tons of a value of £610,100 in 1891, and to 78,517 tons of the value of £1,956,950 in 1898, the increase has taken place about equally on the outward and homeward voyages. There has been a similar satisfactory increase in the traffic returns between Bombay and East Africa. A considerable impetus has also been given to shipbuilding in Germany, as nine vessels of a total register of 25,603 tons have been built there for this mail service, costing £550,000. Tables are also given in the original, showing how the lines have increased the consumption of coal and provisions of all sorts in Germany. Passenger traffic has also increased, whereas only 1,443 persons were carried in 1891, the number was 9,922 for 1898 of all classes. The Paper shows clearly that the Government is most anxious to encourage German trade in these regions. E. R. D.

The Failure of the Masonry Dam at Austin, Texas.

(The Scientific American, April 28, 1900, p. 256.)

This dam, situated 2½ miles above the city of Austin, was completed in 1893; it measured 1,125 feet along the crest, which was 65 feet above the bed of the river. Its downstream profile was curved at the top to accommodate the overflow, and there was a reverse curve above the outer toe; the bottom breadth was 66 feet. The foundation of the dam was on limestone, and considerable trouble was experienced during construction from springs

in the bed and banks of the river, and after completion from water forcing its way through the underlying rock. The structure was built with a hearting of rubble limestone laid in Portland cement mortar and faced with granite. At the time of the disaster there was 11 feet of water passing over the crest of the dam; it gave way vertically at two points, one 100 feet from the eastern end, and the other about the centre. The 440 feet length between these points was pushed bodily downstream for a distance of 40 or 50 feet, retaining its vertical position during transit; it then broke into two pieces, and the greater portion crumbled away, owing to the undermining action of the water.

The impact of the falling water had apparently worn away the limestone rock below the outer toe, leaving nothing but the frictional resistance between the base of the masonry and its foundations to oppose the downstream thrust of the water.

A. W. B.

The Need of Uniformity in the Bacterial Analysis of Water.

DR. FRANCESCO ABBA.

(Zeitschrift für Hygiene, vol. xxxiii., 1900, p. 372.)

It is pointed out that comparisons of different bacteriological analyses are rendered in many cases fruitless by the diversity in the practice of the various experimenters. The results cannot be uniform in which the temperature under which the cultures are carried out, the period of incubation, and the alkalinity or the composition of the gelatine medium vary. The Author lays down certain data for general acceptance, and proposes for the nutritive gelatine a substance whose composition is as follows:—

	Grams.
Concentrated Bouillon from Liebig's Extract of meat . .	6
Fish Glue (Gelatine)	150
Distilled Water	1,000

The addition of salt, peptone, and other similar ingredients is unnecessary. For various reasons carbonate of soda in the proportion of 0·5 per mille is proposed for the standard of alkalinity, after the addition of sufficient alkaline solution to give the characteristic rose-tint with 3 per cent. alcoholic phenol-phthalein solution. The Esmarch method is not recommended for cultures, but that of Koch, with Fischer's modification of the plan of Petri. The temperature for incubation to be from 18° C. to 19° C., and to be in all cases constant. The period of incubation to be as prolonged as possible—15 days is suggested. The number of colonies always to be stated as those present in 1 cubic centimetre of water. No investigation of water of unknown origin to be undertaken nor of samples procured by unreliable observers. These data were discussed at the Como Hygienic Congress, and a resolution was passed in favour of uniformity in procedure. G. R. R.

The Linde and Hess Process for the Removal of Iron from Water.

(Gesundheits-Ingenieur, 15 April, 1900, p. 105.)

It is pointed out that, owing to the increasing pollution of rivers in Germany, it becomes more and more difficult to make use of superficial supplies of water for drinking and domestic purposes, and for many years past engineers have been compelled to seek for supplies of underground water. Among other cities to resort to subsoil water for public-supply purposes mention is made of Breslau, Magdeburg, Hamburg, and Berlin. Water from the upper layers of the soil generally contains iron in such quantities as to prohibit its use for drinking purposes and also for various industries here enumerated. If iron is present as the carbonate of the protoxide, all that is needful to remove the greater part of it is to convert the soluble protoxide into the insoluble sesquioxide of iron by free exposure to the air, and to clarify the water by subsequent filtration. This, however, involves two independent processes: firstly, the division of the water into rain or spray, and, secondly, the treatment in the filter. These two processes are replaced by one operation in the plant devised by Mr. H. v. d. Linde and Dr. Hess, which is here illustrated and explained. The water is treated in a filtering vessel filled with wood shavings, free from turpentine and impregnated with oxide of tin. The oxygen required for combination with the iron would seem, as there is no contact with the air, to be derived from the water itself. The hydrated oxide of iron arising from the treatment is retained by the shavings in the form of a brownish-red deposit. As there is no need of mechanical admixture with the atmosphere in this process a considerable part of the pumping is saved. Details are given of the size of the filters and of the cost of working. As the shavings get gradually clogged with the deposit, it is necessary to change and cleanse them about every 2 months. Every 12 hours the filters have to be washed out, air and steam being also blown through them in a reverse direction. In some works at Gladbach, which are here described, the total cost of the plant was £2,500, and the annual expense of filtering 165 million gallons of water for labour, materials, and interest on capital, was £389.

G. R. R.

The Disposal of the Berlin House Refuse.

(Gesundheits-Ingenieur, 15 May, 1900, p. 140.)

In further reference to the experiments at Berlin with the Wegener process,[1] in which the ashes and domestic refuse are fused in a species of cupola furnace, it is stated that though the

[1] Minutes of Proceedings Inst. C.E., vol. cxxxviii. p. 508.

ultimate results obtained were, upon the whole, satisfactory, it has been decided by the municipal authorities, after careful trial, to discard this system of treatment in favour of the Buda-Pesth plan, which is one in which the refuse is first sorted and the valueless residue only is consumed. From previous experiments it has been ascertained that the refuse of Berlin cannot be consumed alone in furnaces of the ordinary kind, owing to its high percentage of ash; and though the proposed system of separation will lead to the collection of certain substances of value—wood, paper, rags, glass, bones, pottery, tins, etc., it is doubtful if the residue can be burnt up without the addition of fuel. It is pointed out that the question here is not that of the profitable disposal of the refuse, but is intimately connected with sanitary considerations. It is doubtful whether the sorting system as now practised is free from objections from the health point of view, as the rubbish contains many rags, old clothes, etc., liable to convey infection from the sick room. In Hamburg, where a similar sorting process was employed, this plan has been given up since the cholera epidemic, and the house refuse is now burnt unsorted. Wegener has asserted that his process of fusing the refuse may readily be arranged in connection with a series of boilers in which the surplus heat would be utilized, and that by this means the cost of the treatment would be greatly reduced.

It is intended during the present summer to carry out some experiments in Berlin, and to employ the residual gases, which leave the furnaces at 1,400° C., for the production of steam, which will drive a set of dynamos. The furnaces will melt 25 tons of refuse per diem, with the addition of 30 per cent. of coal dust, the total amount of clinker produced being 8 per cent. of the whole bulk dealt with.

G. R. R.

The Sewage-Irrigation Works of Brandenburg.

E. Bernhard.

(Gesundheits Ingenieur, March 31, 1900, p. 89.)

The sewage water of Brandenburg, a town of 45,000 inhabitants, situated on the River Havel, is brought into a collecting-tank near the river, and from thence conveyed by a 23·6-inch rising main of cast-iron to the summit level of the irrigated land, at a distance of about 3¾ miles. The water is distributed by means of special cast-iron carriers, which are provided with 8-inch penstocks at their extremities. The land selected for irrigation lies in the centre of the forest tract belonging to the town, and comprises at present an area of about 267 acres; but a further area of 494 acres is available for extensions. A plan of the works is appended to show the position of the carriers and the under-drains. The drainage passes into the River Buckau, which flows into Lake

Breitling. The level of the underground water sinks naturally towards this lake. The ditches and drains have a fall of 1 in 1,500. The under-drains are laid 3 feet 3 inches deep, with a fall to the collecting-drains of 1 in 200. The collectors have a fall of 1 in 300. The plots are rectangular in form, the roadways being at right angles to the main ditches. The plots which have the greatest slope are used for meadow-grass, and those which are more level serve for the growth of beetroot. The works were started on 1st July, 1899, and have been leased for a term of years to a contractor at a sum which pays the interest not only on the expense of laying out the ground, but also on the entire cost of the undertaking.

G. R. R.

Dry Distillation of Fir Wood. IRMINGER.

(Ingeniøren, Copenhagen, 1899, pp. 311–317.)

A Danish company having to fell increasing quantities of fir in order to make room for the growth of young spruce, their ranger, Mr. Dalgas, tried burning the wood in a kiln of Russian pattern, built on their Birchbeck plantation. It is a vault of thin brick-work, within which is stacked about two cords of wood; and it is encased by an outer brick vault, with an intervening space, wherein are two fireplaces, in which the commonest portions of the wood are burnt as fuel for heating the kiln; the smoke escapes through an opening opposite to the fireplaces. The outlet from the kiln itself is through the floor, whence the tar flows through an iron pipe into barrels, while the gas is not utilized. The burning lasts about two days and nights. As this manufacture is somewhat new in Denmark, the Author offered to test the wood in the small retorts and other apparatus used for testing coal in the gasworks under his management. Besides fir he tried also spruce, birch, beech, and oak; of the fir some lots had been cut four years, some were only fresh cut, others were green brushwood, and brushwood of a year's growth, and others were young and old cones.

The mode of conducting the tests is described in detail, together with the apparatus employed; and the results are voluminously tabulated in two sets, according as the limit of temperature reached in the burning was about 600° C. (1,100° F.) in the course of two hours, or about 700° C. (1,300° F.) in the course of only one hour. The total weight of the products of distillation—gas, pyroligneous acid or wood vinegar, tar, and charcoal—was within 4 per cent. of the weight of the wood charged into the retorts. With the higher temperature the gas was more abundant and its heating power greater, whilst its specific gravity was lower, owing to its containing a smaller quantity of carbonic acid. The pyroligneous acid was about the same with both temperatures. The tar was rather less plentiful with the higher temperatures,

except from the green brushwood, the cones, and the spruce; the charcoal was considerably less. Agreeably with practice therefore the burning should be done at a low temperature, not above dark red, and the heat should be got up slowly. Brushwood and cones can be utilized with advantage, except as regards their resulting charcoal, which is worthless. It is better, especially when tar is the chief product aimed at, to use wood which has been longer prepared for burning, since the formation of resin is constantly going on, and even continues in the stumps after the trees have been felled. Turpentine was not found in appreciable quantity in the fir distillates, except from particularly resinous wood yielding a great quantity of tar, which is of lower specific gravity than the pyroligneous acid or wood vinegar. The turpentine boils at about 180° C. (356° F.), but a great deal distils over at a lower temperature. It is hardly worth recovering, except from the most resinous trees, and especially from their stumps. Of wood spirit (methyl alcohol) no more than a trace is found in the fir distillates; it is recovered only from leafy trees, particularly oak and beech. Oak, and especially beech and birch, rank high in yield of vinegar, both in quantity and in strength. The crude gas evolved is not illuminating until purified, but can be used for lighting in conjunction with the Welsbach mantle; a light of about 36 candle-power is thus obtained when burning 3 cubic feet of gas per hour. If the fir wood is put into a red-hot retort (about 1,100° C. or 2,000° F.), it yields 7,600 cubic feet of gas from 1,000 lbs., with a heating power of 460 thermal units (lbs.-Fahr.) per cubic foot. With so much gas the quantity of tar is small, the pyro-ligneous acid is diminished, and the charcoal is materially less. Owing to the primitive arrangements for condensation at the Birchbeck kiln, the results there obtained are inferior, showing the importance of improvements if the distillates are to be recovered; enough condensing water should be used to cool them down to about 20° or 30° C. (68° to 86° F.). As the crude gas distilled from 1,000 lbs. of wood can be burnt with as good heating effect as 4,000 lbs. of the wood itself used as fuel, it is recommended to heat the wood-burning kiln with its own gas from the condenser, inserting a wire-gauze diaphragm in the gas pipe to prevent risk of explosion. A number of tests were also made by the Author on five lots of pyroligneous acid recovered from fir, with reference particularly to its use for tanning; and the satisfactory results are detailed. As a preservative for wood, it is better to use purified wood vinegar, which contains more creosote than the acid; the wood is coated three times over with the warm liquid. The purified acid is used abroad on a large scale for making vinegar; and also in the preparation of mordants for cotton-dyeing. As it is so dear in Denmark, it is desirable that its production inland should be developed as a home industry.

A. B.

The Design of Rotary Converters.

H. F. Parshall, M.Inst.C.E., and H. M. Hobart.

(Engineering, 22 October, 1899, pp. 450 and 517.)

The winding of the continuous current portion of a rotary converter is exactly the same as in an ordinary direct current dynamo, the conductors being led down to the commutator at frequent intervals. For a single-phase alternating current, a tap is led from any point of the armature to one slip-ring, and after tracing round exactly one-half of the circumference, another tap is drawn to the second slip-ring. For three-phase, in a two-pole machine when ring wound, the circumference must be divided into three equal sections, and a lead taken from the three divisions to three slip-rings. When there are more than two poles, the same principle is carried out, regard being taken of the number of poles; the winding may also be arranged so as to have two or three complete circuits acting in parallel for each phase. The Author gives numerous diagrams of various kinds of windings. Single-phase converters are seldom used except for small outputs on account of the imperfect overlapping of alternate and direct currents in the conductors, while there is the additional difficulty of running them up to synchronism from the alternate current end; the same does not apply to polyphase converters, as these act as induction motors between starting and synchronism. In winding three-phase converters, the overlapping of the conductors round the armature reduces the efficiency of the machine. Any one portion of the periphery contains conductors belonging to two adjacent phases. Thus at one portion they belong to phases 1 and 2, at another to 2 and 3, and at another to 3 and 1, the repetition occurring once every pair of poles. Thus the conductors supplying any one phase spread themselves over two-thirds the entire periphery, and as the flux, on account of spreading, occupies about three-quarters, the conductors can never be free of flux, and the rate of cutting, and consequently the electromotive force generated, must be reduced. This condition is improved in six phasers, where the conductors belonging to phase 1 overlap with phase 4, 2 with 5, and 3 with 6. Thus the number of conductors supplying one phase occupies only one-third the periphery, and an almost simultaneous linkage of the whole flux is obtained. The output of such a machine is 44 per cent. greater than for a three-phase converter with equal armature ohmic losses.

A. P. H.

Interconnection between Static and Rotary Transformers.

H. F. Parshall, M.Inst.C.E., and H. M. Hobart.

(Engineering, October 27, 1899, p. 517.)

In the case of three-phase converters, driven by alternating currents from static transformers, the transformers should be connected up in the "delta" combination to the three lines leading to the three slip-rings of the converter. This allows the latter to continue running, even if one transformer be temporarily cut out for repairs, for if lines 1 and 2 be joined to one transformer, and 1 and 3 to the second, there will still be an alternating electromotive force between lines 1 and 3, even when the transformer usually supplying them is cut out. This electromotive force will of course not be in its proper phase or magnitude, and will result in a temporary want of balance of the system. In the case of a six-phase converter, three transformers are used, the six secondary wires being led to the six slip-rings. There are two principal methods of connection, viz., the "double delta" and "diametrical." Taking an imaginary circle to represent the winding, then six equidistant points are the positions for conductors leading to the six slip-rings. If diametrically opposite points be connected to one secondary winding, the combination is called diametrical, whilst if Nos. 1 and 3, 2 and 4, etc., are so treated, it is a double delta, being in fact an exact doubling of the delta combination, as used in three-phase converters. In the latter the ratio of alternate to direct-current voltage is the same as in a three-phase converter, whilst the diametrical system gives the same ratio as in a single phase, being an exact trebling of the latter arrangement. The Author describes suitable switchboard arrangements for four converters, the alternate-current part being kept to the left, and the direct to the right.

A. P. H.

Design of a Six-phase Rotary Converter.

H. F. Parshall, M.Inst.C.E., and H. M. Hobart.

(Engineering, December 8, 1899, p. 721.)

In designing a converter with fixed requirements the number of poles is first decided. With an assumed periodicity the speed is inversely as the number of poles. High speed and few poles will give the best results, within certain limits, for a given amount of material used. In continuous-current generators the number of conductors is affected by armature interference due to cross and demagnetising turns. In the case of rotary converters, however, the resultant current through the armature is so small that this

question is not important, and as many conductors may be used as room will allow. The reversal of current when a particular commutator segment is under the brush presents a difficulty in the design of these machines. As the flux is usually of small density the reversal must be as it were forced and not natural, as in the case of a continuous-current generator. Again, the speed of a rotary converter is usually two or three times as high as a continuous-current generator of the same output, and this is an additional reason for keeping the inductance of the armature coils as low as possible. "Surging" troubles are often noticeable in the pole faces of rotary converters, owing to non-uniformity in angular velocity of the engine driving the generator alternator. If the pole faces be solid and not laminated, these surgings induce currents in them, and the two react on one another. Surging can also be prevented by laminating the pole faces and embedding suitable copper conductors for these induced currents. The Author gives a list of principal dimensions for a converter, and a diagram showing losses and efficiency for various loads.

A. P H.

Ohmic Losses in Rotary Converters.

H. F. PARSHALL, M.Inst.C.E., and H. M. HOBART.

(Engineering, September 29, 1899, p. 389.)

Rotary converters are used for transforming alternating into continuous currents, or *vice versa*, the former being the more usual. Comparing a rotary converter with an alternate-current transformer the alternate current corresponds to the primary of the transformer, and the direct to the secondary. The two currents in the converter are always in opposition to one another, and render it possible to have small armature conductors to deliver a given direct current. Although any one conductor may be receiving a large alternating and delivering a large direct current at any one instant, yet since the two are opposed the resultant current through the conductor will be small. The Authors also point out the effect of the lagging of the alternating current. Should the alternate current lag behind the pressure the current is less efficient in the ratio of $\cos\phi : 1$, where ϕ is the angle of lag. Hence to have the same direct current output, and assuming the pressure of the alternating current to remain constant, the current must be increased in the ratio of $1 : \cos\phi$. This in turn involves greater ohmic losses in the armature conductors. Again, the number of phases affects the question, for, to keep these ohmic losses small, the resultant current flowing through the armature must be as small as possible. A three-phase current will raise the average alternating current flowing through a given conductor, and consequently keep the average difference between direct and

alternating lower than in the case of a single phase. The Authors give Tables and data showing the relative output for equal armature C^2R losses of rotary converters of various power factors and phases, and a direct-current dynamo.

A. P. H.

Choice of Current for Electric Supply. Bull.

(Teknisk Ugeblad, Christiania, 1899, p. 470 *et seq.*, 1900, p. 4 *et seq.*)

The various questions determining the choice are severally considered in detail by the Author, commencing with the tension to be employed. This will depend upon the distance to which the electric current is to be supplied, and the purpose for which it is to be used.

A careful comparison between alternating-current and direct-current dynamos is summarized as follows. Where there are not other conditions deciding the choice of current, high-tension alternating-current dynamos should be chosen for larger supplies, low-tension direct-current for middling and all smaller. Of direct-current dynamos, shunt-wound should be preferred where several are employed, and where the engines do not run quite steady; compound-wound for small stations with well-governed engines; series-wound under special circumstances only.

Next in importance to dynamos comes the switchboard, which must be practically arranged, and fitted with trustworthy instruments. There is no difficulty with low-tension and weak currents, only with high-tension and strong. For high-tension alternating currents the shunt resistance of ampere meters are replaced by a small reducing transformer, whose primary coils are in series with the circuit of the current to be measured, while the secondary convey a low-tension current to the meter. Volt meters are difficult and unsafe to use for more than 1,000 to 1,200 volts of direct current; with alternating current a reducing transformer can be interposed. Watt meters are much simpler for alternating current than for direct. Cut-outs and safety-fuses are equally suitable generally for direct and alternating currents of low tension; with high tension the alternating-current appliances are both more convenient, more trustworthy, and safer; the cut-outs however are simpler for direct current.

Alternating-current transformers offer great advantages over those for direct current. They are stationary, require no attention, and can be constructed for any amount of power, while their efficiency rises to 96 or 98 per cent., and they will transform down to 1–25,000th of the primary current. Direct-current transformers are double machines, in which one part works as motor and the other as dynamo; they require care and attention, and their efficiency ranges between 71 and 87 per cent. A special class of transformers are the two kinds of converters,

which convert alternating current into direct, or conversely: one kind are double machines, with a motor driving a dynamo; the other kind are the so-called rotary converters, which are single machines. High-tension current requiring conversion can be led direct to the double machines, whereas for rotary converters the tension must first be reduced by a static transformer. Rotary converters present so many advantages over double machines that they are always to be preferred.

Of accumulators there is only one kind, namely chemical batteries which are more expensive than an equivalent number of dynamos. As they cannot be charged by an alternating current, they involve the employment of a converter wherever alternating current is used. They are needed wherever sudden fluctuations of current occur, and great variations of load: as on electric railways or tramways, in hoisting appliances, or in works driven by gas-engines and benzine motors.

For the electric mains or conductors three-phase current is best in respect of economy; next comes direct current; and last alternating.

Of electric motors, those driven by alternating current are either synchronous or asynchronous, and each kind is either single-phase, two-phase, or three-phase. Synchronous have the same constructional advantages and defects as alternating-current dynamos. Their efficiency is high, even with light loads; but they are easily pulled up by overload. Three-phase synchronous motors are preferable to either single-phase or two-phase. They are employed most advantageously where great power has to be conveyed from a primary to a distant secondary station containing a few large motors.

Asynchronous alternating-current motors are advantageous where the tension is high; where attendance has to be limited to the least possible; where it is important the motors should maintain the same speed, even if the load or the tension varies; where the machinery is much exposed to dirt; where there are explosive or inflammable gases or atmosphere; and where great safety of working is desired. They are less suitable where the speed has to be varied, as on an electric railway; where small low-speed motors are desired; and where the motors run for longer periods with a light load. Three-phase motors are again the most advantageous; they are easily started under a heavy load, and are smaller and cheaper than single-phase or two-phase.

Direct-current motors are either series-wound, shunt-wound, or compound-wound. Though they can be constructed for any tension, they are less suited for high than for low. Series-wound should be used only where large turning moment must be developed for starting heavy loads, as on tramways, and where there is no harm in the speed varying inversely with the load. For high tension, several motors and several dynamos are coupled in series, along with the engines and other apparatus, so that the whole form a single closed circuit. This plan, known as the Thury system, has been working

ten years in Switzerland, and is said to have been attended with no serious mishaps. The dynamos have to furnish current of constant strength, and of voltage corresponding with the power required. The full strength of current is sent through the armatures of the motors, but not through their magnets; the latter are magnetized by a regulator in proportion to the load on the motor. The advantages of the plan are enumerated at length, as well as its defects.

Shunt-wound direct-current motors are suitable where uniform speed is desired; where the speed is required to admit of being regulated; where there are small motors, which are to run slow; and where the motors generally run not fully loaded. They are less suitable where large masses have to be set in motion; where the attendance is limited, and the motor is exposed to dirt; and where there is danger of fire from inflammable gases.

Compound-wound direct-current motors combine many of the good properties of series-wound and shunt-wound. They are specially suitable for great starting power and uniform speed.

For lighting, direct current in general is throughout better than alternating for the supply of glow-lamps. In arc-lighting with direct current the chief light is thrown in the direction towards which the positive carbon faces; with alternating current it is thrown equally below and above the arc, but is accompanied by hissing of the arc.

The foregoing is but a bare indication of the course pursued by the Author in his detailed examination of these several branches of the subject; and he sums up his recommendations as follows.

High-tension Current. Power-supply only:—if there is one primary dynamo and one secondary, the synchronous alternating current, preferably three-phase, should be used for tensions over 3,000 to 4,000 volts; with tensions from 3,000 down to 500 volts, synchronous alternating current for large power up to 200 or 300 HP.; and for lower power, direct current, with the wires joined up in series if the conditions allow of this. If there are several large secondary motors, the Thury plan is to be preferred, or else synchronous three-phase current. If there are several small secondary motors, three-phase current with transformers should be used; and for the smallest motors the Thury plan, where the works using the current are suitably situated for it. Lighting only:—for larger stations preference should be given to three-phase current with stationary transformers; for smaller stations, alternating current with stationary transformers; and where accumulators are required, three-phase direct current and rotary converters with stationary transformers. Combined power-supply and lighting:—If power is paramount, three-phase current with stationary transformers is recommended, eventually with rotary converters for lighting; if lighting is paramount, three-phase or alternating current with stationary transformers. Central stations:—three-phase current with stationary transformers is best, and separate mains for lighting and for power; if the power mains are to

supply existing lighting centres, it is best to employ rotary converters with stationary transformers.

Low-tension Current. Power-supply only:—if there is only a dynamo and a motor, direct current of 500 volts should be used for small supply, and synchronous three-phase current for larger. If there are several motors, three-phase current is preferable, where the motors are not required to fulfil special conditions; direct current, where the motors run with light load or at a low speed or are desired to admit of being regulated, or where accumulators are required. Lighting only:—direct current should exclusively be used, eventually with accumulators. Combined power-supply and lighting:—if power predominates, three-phase current is preferable, eventually with direct current for the lighting mains; or direct current for smaller stations, and where an accumulator is wanted for the exciter; if lighting predominates, direct current. Central stations:—direct current for smaller, and three-phase current for larger.

Various Applications. For lighting of ships and for movable lights, direct current. For tramway working, direct current with buffer battery. For calcium-carbide manufacture, preferably alternating current.

A. B.

Cost of Electrical Power in Copenhagen. C. Hentzen.

(Ingeniøren, Copenhagen, 1899, pp. 299–300.)

As manager of the municipal electrical station the Author furnishes the cost of driving electric motors in various works supplied from the station. Smaller motors take about 900 watts per horse-power; and the present price being 2*d.* per kilowatt per hour, one HP.-hour costs 1·8*d.* for electricity, or one HP. costs £22 10*s.* per year of 300 days of 10 hours. At present there are some 325 motors connected with the electric mains, of which only a few pay so large a sum yearly, and these are in works where they are used considerably more than 3,000 hours a year; generally the annual expense is considerably less, according to what the motor has to do. For driving elevators and hoists the yearly cost has averaged 39*s.* per HP., rising in one instance to about £11. Printing works average £6 19*s.* per annual HP.; one rises to about £11, while a number are under £5 10*s.* Wood-working, spinning, and weaving machinery, and smaller factories average £7 5*s.*; a few run up to £11 and £16 10*s.*, while a great many are under £5 10*s.* Small motors of about ½ HP. are in favour for working coffee-mills, and pay from £5 10*s.* to £22, averaging £11 per annual HP. Motors from ½ to 1 HP. are arranged for pumping automatically from a sump at a yearly cost of about £3. Ventilators are being driven to any extent from only a few hours a year up to more than 3,000. Other applications are to sewing

machines, centrifugals, butter-kneading, mincing, bookbinding, winnowing, colour-grinding, dentistry, bottle-washing, polishing, calendering, and many more. For large motors also it will pay to take electric current from the station, in place of using independent steam-power on which must be charged interest and redemption. Certainly within the range of the electric mains no independent power ought to be employed under 20 HP., unless the waste steam can be utilized, or unless Dowson gas, for instance, can be used in some other way.

A. B.

Norwegian Waterfalls and Electricity. C. N. A. Solberg.

(Teknisk Ugeblad, Christiania, 1899, pp. 547–552.)

The larger rivers in Norway, south of Trondhjem, are estimated at their lowest capacity to yield about 263,000 HP., which by proper control of the watercourses could probably be increased fourfold. At present something over 50,000 HP. is believed to be all that is utilized for industrial purposes from the waterfalls. The use of electricity generated by this means is dealt with by the Author—a director of the Norwegian Electric Company—for lighting, power, railway traffic, heating, and chemical and metallurgical processes.

Lighting.—Hitherto it has not been sufficiently realised at how low a price electric lighting can be done on a large scale, nor how large a consumption can be reckoned upon when the price is low. In five years' working at Lillehammer, with 2,000 inhabitants and considerably over 2,000 lamps of 16 candle-power supplied from the electric station, the price has been only 7·2 kroner (8*s.*) per lamp per year; yet the station has more than repaid the capital outlay, and 200 HP. has already become insufficient for its requirements. For Christiania, with 220,000 inhabitants, lighting on a corresponding scale would require over 20,000 HP. As water power is used for lighting for an average of scarcely 1,000 out of the 8,760 hours in a year, a great economical advantage will be enjoyed by any industry which can utilize electric power during the hours that the electric station is lightly loaded, and which can be content with less during the hours of lighting. Electric lighting may be expected in future to appropriate more power from the waterfalls, especially in view of the extensive possibilities opened up by the Nernst lamp[1] and many other inventions, whereby the consumption of current in incandescent lamps is diminished.

Electric Power Supply in such a country of waterfalls is at present sadly behind-hand. The great advantages of employing electric driving power in factories are pointed out and illustrated

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[1] Minutes of Proceedings Inst. C.E., vol. cxli. p. 396.

by the Author. In this application however he fears the expectations of a golden age to be inaugurated by electricity have been raised far too high.

Traction by electricity has not yet been adopted on any main railway, in spite of its recent rapid development on tramways and suburban lines. On Norwegian railways the traffic is not sufficient for electric working to pay. Even tramways are as yet needed to a limited extent only.

Heating by electricity can only under special circumstances be thought of for industrial purposes. Current equivalent to 2·2 lbs. of coal, or 11 HP. hours, may be reckoned to cost 4·4 to 5·5 øre (0·59*d.* to 0·73*d.*) For domestic use however the conditions are somewhat more favourable to electric heating, owing to the excessive waste of fuel in the various heating appliances hitherto employed in houses. A good old-fashioned kitchen-range is suspected of utilizing no more than 2 per cent. of the calorific value of the fuel. Other advantages of electric heating are its great cleanliness, and the ease with which the heat can be got at the very place where it is wanted. The greatest drawback is the relatively high cost of the electric heating apparatus; in spite of which, electrical cooking and ironing are coming into more extensive use, though slowly.

Chemical and Metallurgical processes are already making more and more use of electricity. At the Sarp waterfall nearly 10,000 HP. are employed, mostly in the manufacture of calcium carbide at the Hafslund and Carbide Industry works; while a cellulose factory at Borregaard employs several hundred horsepower for electrolytic bleaching. Carbide factories are building at Notodden, Christianssand, Hardanger, and Meraker. The electrochemical processes in use may be classified in two groups: electrolytic, in which the chemical reaction is due to electricity itself; and electric smelting, in which the reaction is rendered possible by the high temperature developed by electricity. Commercially the most important applications of electrolysis are to the production of chlorate of potash, caustic soda, caustic potash, and chloride of lime.

The only electro-chemical process which has yet attained much importance in Norway is the manufacture of calcium carbide, for which the temperature required is estimated at about 3,000° C. (say 5,500° F.), and the current strength at from 4,000 to 10,000 amperes. In the carbide works at Sarpsborg a continuous furnace is employed, from which the carbide is tapped out at intervals, like metal out of a foundry cupola; here the furnace has been running continuously for fifteen months without interruption. In another works an intermittent furnace is used, in which a large mould is filled with the carbide as it is produced, and as soon as full is removed and replaced by a fresh mould. By either method good carbide is obtained, so that the choice depends on the conditions of working; the Author himself prefers the continuous plan. The inland waterfalls are unfavourably situated for this manu-

facture, because it is then saddled with the cost of conveying the finished product down to the coast and the raw materials up to the falls, whereby the chief advantage of the cheap water-power is lost. One merit of the carbide manufacture in a comparatively poor country is that it requires little capital.

Aluminium manufacture is also likely to become extensive in Norway, especially in connection with steel-making, which absorbs about three-quarters of the present production. At the existing high price of copper, aluminium can moreover compete with this metal. Provided the right mode of manufacture be adopted, works of 3,000 to 4,000 HP. would pay well; the capital required would be about 2 million kroner (say £110,000), including purchase of water-power. Of other electro-metallurgical processes the more important are probably the cyanide process for extracting gold, and electrolytic copper-refining.

Any of these industries successfully prosecuted by means of her waterfalls would make amends to Norway for her want of coal, whereby her mining operations are so seriously impeded.

A. B.

The Water-Power Electricity Works in Geneva.

E. Baumann and Others.

(Schweizerische Bauzeitung, 1900, p. 100. Figs.)

A portion of the technical education course at the Swiss Polytechnic consists of excursions to visit important engineering works. An excursion of the 3rd and 4th year students under Professors Prasil and Wyssling was arranged to visit the recently-enlarged electricity works at Geneva, and the original article consists of a report upon this visit by three of the assistants at the Polytechnic.

The hydraulic works at the Coulouvrenière were first examined, and references are given to detailed descriptions which have already appeared in the *Schweizerische-Bauzeitung* and in the pamphlet by Mr. Turettini. It may, therefore, suffice to say that practically the whole width of the Rhone is used for power production. The plant is divided into two parts, one of which supplies service, power and drinking water, and the other electricity for light and power to Geneva and its neighbourhood. The water-supply plant consists of eighteen turbines, each of 200 HP., each of which drives direct two twin pumps by Escher, Wyss and Co.

Quite recently a high-pressure centrifugal pump by Sulzer Bros. has been added, which is driven by a 1,000-HP. two-phase electric motor, and is used to pump the water into a large storage reservoir 460 feet above the Rhone level, whence it flows to supply power for water motors in Geneva. The electric motor was built by Brown, Boveri and Co., and is of the asynchronous type. The

electrical installation at Chèvres is of the chief interest, and consists of (1) the plant in the old waterworks building, consisting of eight dynamos, each of 100 HP., feeding a 110 volts network; (2) the monophase alternating plant; (3) the generating plant for the power transmission to Secheron; (4) the plant for the municipal electric tramways. The last three are all in the Coulouvrenière.

The Authors then give a detailed description of the whole plant and illustrate the chief parts. One of the recent additions consists of rotary transformers by Alioth, which receive the two-phase alternating current at 425 volts and give out direct current at 600 volts; the two windings are placed upon the same armature. At Chèvres the weir takes up the entire width of the Rhone and is fitted with Stoney sluices. The power plant consists of fifteen turbines by Escher, Wyss and Co., with the generator fixed direct upon the vertical shaft, each of five develops 1,200 HP. in winter with the maximum fall of water, and they run at 80 revolutions per minute. The remaining ten are of an improved type, each being so designed that one-half takes the high winter fall, and the other half the low summer fall. The generators driven by the first five turbines are of the Thury type, but of the ten recently added six are by Messrs. Brown, Boveri and Co., and four of an improved Thury type. One only is for direct current; all the others produce two-phase alternating current at 2,500 volts with a frequency of 45 per second. The new machines are illustrated in the original Paper.

E. R. D.

The Electrical Installations for Lausanne.

(Schweizerische Bauzeitung, 1900, p. 124.)

The town of Lausanne has acquired from the body controlling the water-power of the Rhone at Saint-Maurice the right to the use of a waterfall 113 feet to 118 feet high, obtained by impounding the Rhone above Saint-Maurice. The power available is about 6,000 HP. during the dry season, and reaches 14,000 HP. for 10 months in the year. This power will be used for the supply of electrical energy to Lausanne.

The works which are now in progress were designed by a Commission composed of Messrs. Butticaz, Wagner, Chavannes, Bellenot, and Jung. The plant will at first consist of five turbines with horizontal axis, each developing 1,000 HP. at 300 revolutions per minute, and each will drive two generators producing 150 amperes direct current. The ten machines will be connected in series, and will give a total of 22,000 volts, and the direct current thus produced will be taken to Lausanne 35 miles distant by overhead wires with a loss of 10 per cent. Close to the town the receiving station will be built, with five motors in series, each of

400 HP. Each will drive a triphase alternator giving 3,000 volts, or 1,730 volts per phase, and two will also be so arranged as to be driven by steam-engines as a reserve.

The triphase current will be taken to sub-stations and transformed to 125 volts. This unusual system has been adopted for the following reasons: the population of Lausanne is very scattered; if alternating current had been brought direct from Saint-Maurice, the potential at the lamps could only have been controlled at Saint-Maurice, which would have been very inconvenient; the same plant must be capable of supplying direct current at 500 volts or 600 volts for the tramways. The series system has been previously used at Chaux-de-Fonds and at Locle, and is considered much more economical than the double transformer system with a tension of 15,000 volts.

The hydraulic works and building at Saint-Maurice is being carried out by J. Chappuis, the pipe work and turbines by Escher, Wyss and Co., the generators and electrical plant by the "Cie. de l'Industrie Electrique" of Geneva, and the transmission line by Professor Palaz. The triphase alternators at Lausanne are being built by Alioth, and the reserve engines by Sulzer Bros. The supply of current will be begun early in 1901, but the hydraulic plant will not be ready until November, 1901.

E. R. D.

The Barmen-Elberfeld-Vohwinkel Elevated Railway.

(Archiv für Post und Telegraphie, 1900, p. 193.)

The elevated railway on the system of Eugene Langen of Cologne was described in the Archiv in 1894, p. 408, and in 1895, p. 90. It was proposed to adopt it in Berlin, but as yet nothing has been done there, while at Barmen-Elberfeld it has now come into practical use. The two towns, inclusive of the suburbs of Vohwinkel and Sonnborn, have a population of 300,000, and a better means of local transport was greatly needed.

The construction was carried out by the Continental Co. for electrical undertakings of Nuremberg. The railway begins at the Barmen-Rittershausen railway station, follows the course of the Wupper through Barmen and Elberfeld, passes through Sonnborn and Vohwinkel, and terminates at the State railway station of Vohwinkel. It is expected that the entire line will be ready this summer, as a length of about 872 yards was completed early last year. The railway appears to be of similar design to that known as the Lartigue system, and has only one carrying rail. The sharpest curve upon the main line has a radius of 295 feet, but near the Vohwinkel terminus there are some of 98·4 feet radius; the steepest gradient is 4·5 per cent., and gradients and curves are so chosen that the speed of 24·8 miles per hour can be

always maintained. The tests were made with a car carrying fifty persons, and although in rounding curves the angle of the car was 25° from the vertical, the running was perfectly smooth. Each car is carried upon two four-wheeled bogies, and has two motors producing 36 HP. at 500 volts. It is expected that by the use of the block system a 2-minute service of trains will be obtained.

The stations are large enough to accommodate trains of four cars each, with seats for thirty persons and standing room for twenty more. It will be possible to carry 6,000 passengers per hour in each direction. The railway is carried across the river Wupper; in the streets the trestles are arranged on the side walks, and the height of the track above the road is about 14·76 feet. The cost of the railway, inclusive of station-buildings and ground works, is, at the present price of iron, £36,300 to £40,300 per mile. The extra cost of cars and electrical apparatus depends, of course, upon the traffic, but, with a 3-minute service of a train carrying 100 persons at a speed of 24·8 miles to 26·0 miles per hour, the cost per mile of two-track railway would be £56,400, while the Author states that the cost of the electrical elevated railway in Berlin has been about £161,100 per mile, and the London railways from £209,670 to £644,400, and in some parts even to £838,680 per mile. From this he deduces the great advantage of the single rail elevated railway.

E. R. D.

The New Telephone Act in Germany.

(Archiv für Post und Telegraphie, 1900, p. 33.)

In the original article the Author gives a detailed report of the second and third readings of the new Telephone Bill before the German Reichstag. The Act came into force on the 1st April, 1900, and the complete text is given in the journal.

Each subscriber has to pay a fixed annual rental, the amount of which depends upon the number of subscribers connected to the particular telephone exchange; it varies from £4 per annum for an exchange of fifty subscribers to £9 for an exchange of 20,000 or over; these rates apply to subscribers at a distance not exceeding 3·1 miles from the exchange. Due notice must be given to all subscribers of a rise in rental owing to accession of numbers.

Each subscriber has the option, instead of paying the aforesaid fixed rentals, to pay a fixed sum per annum varying from £3 to £5, according to the size of the exchange, and also a supplementary charge of 0·6*d.* for each conversation, with a minimum of 400 conversations per annum. Rentals are payable quarterly in advance, and the tariff for. conversations does not apply to the lowest rental scale of £4 per annum.

For the use of the trunk lines the charges per conversation of 3 minutes are 2½*d.* for distances up to 15·5 miles, and rise gradually to 1*s.* 6*d.* for 620 miles, and 2*s.* beyond that distance.

There are extra charges for subscribers who reside at a greater distance than 3·1 miles from the exchange, and also for conversations at night, and for cases where several persons make use of one telephone.

E. R. D.

Spanish Government Laboratory for Testing Materials.

LUIS MOYA.

(Revista de Obras Publicas, 1900, p. 73. Figs.)

At the Spanish Government school for engineers of roads, canals and bridges, it had long been decided that a good laboratory for testing materials was essential to a proper course of study, but until a Royal decree, dated 12th August, 1898, was obtained, this work could not be undertaken. The laboratory, which is in Madrid, has now been completed some time; it was built and furnished in 8 months at a cost of £11,500, inclusive of all the apparatus. Although a special building was desired, the sum allowed would not permit of this, and a part of the basement of the school building had to be adapted for the purpose.

For testing mortars the standard sand employed is obtained from the foreshore at Leucate in the Aude (France); but for all ordinary tests sand from the River Manzanares is used.

The laboratory is provided with machine tools for preparing test-pieces, and these are driven by a 5-B.HP. Otto gas-engine. The director of the school, Mr. Inchaurrandieta, has designed the arrangements. Illustrations are given of the various types of testing apparatus in use for cements, metals, oils, chemical analyses, etc.

Permeability tests for agglomerates are made with a special apparatus by Amsler-Laffon of Schaffhausen, and a hydraulic press by the same firm.

A photographic apparatus by Carl Zeiss is used for the microphotography of sections of stone and metal. A small testing-machine for 10 tons, suitable for tension, compression and torsion, by Tincias Olsen & Co., Philadelphia, is in use, and one of 50 tons by Amsler-Laffon, and a larger press of 150 tons capacity by the latter firm.

The laboratory appears also to be well supplied with electrical apparatus by Carpentier, Ducretet, Chauvin and Arnoux of Paris, and Siemens and Halske of Berlin, and the arrangements are stated to be very satisfactory.

E. R. D.

Hollow Cement Blocks for Building.

(Ingeniøren, Copenhagen, 1899, pp. 325–327.)

At various places in Denmark houses have been built of hollow blocks of cement, instead of bricks. According as they are intended for 13½-inch or 9-inch walls, the cross section of the blocks is 13½ × 13½ inches or 9 × 13½ inches, and their length is generally 29¾ inches; the internal hollow, which runs right through from end to end, is square or rectangular; the sides are about 2¼ inches thick, and the top and bottom about 1¾ inch. The mixture of sand and slow-setting cement is rammed dry in moulds in the usual way; after six weeks' hardening the blocks are many times stronger than needed for two-storey houses, and after a year's hardening they bear about 2,000 lbs. per square inch of the wall's horizontal section. The top and bottom faces of the blocks are ribbed lengthways along the edges, and grooved for mortar; the ends are recessed to receive a vertical dowel or wedge of cement, for bonding the contiguous blocks in each course, which thus has a continuous air-space running throughout its uninterrupted length. Each of the larger blocks of 13½ × 13½ inches cross section occupies the space of 75 bricks of the ordinary Danish size, while its weight is only 150 lbs. Corner stones are moulded separately, as are also special blocks for lintels and sills of doors and windows, sole plates for joists, chimney tops, and stoppers for the ends of the air-spaces; these special shapes are made with inlaid strip-iron. Several villas built of these cement blocks have been completed in the course of a couple of months, and have been fit for occupation immediately. The inside of the walls requires neither cleaning nor preparation, but is ready for papering or oil-painting at once; distempering is not so suitable. A factory has also been built in the same way in Christiania.

A. B.

Depreciation of Machinery. R. H. Smith.

(Feilden, vol. viii., March, 1900, pp. 270–281.)

The depreciation of a machine in the course of one year is the change in the capitalised present value of its net earning power, taking into account the probable duration of its remaining life. The capitalised value of the earning value of a new machine is, if it be well chosen and skilfully placed, more than its money cost by the value of the intelligence employed in selection and placing. A mathematical expression is obtained for the depreciation of the present intrinsic and extrinsic value, and curves are plotted from which it is clear that the prevalent notion of decreasing the rate of depreciation towards the end of a machine's life is erroneous:

such yearly depreciation should increase. The Author contends that in a *boná fide* concern the selling value of the plant is altogether a wrong value to attach to machines, instead of their working value. Examples and tabular explanations are given.

M. O'G.

Electric Riveting Machinery. F. v. Kodolitsch.

(Cassier, vol. xviii., May, 1900, pp. 71–74.)

The Author has been experimenting on electric riveting machines, and has succeeded in bringing out two types capable of superseding hydraulic and pneumatic systems. He demonstrates that the initial capital outlay is far less for an electric system than for either an hydraulic or pneumatic installation, while the cost of up-keep is less. As regards the quality of work done, there is no difference, but the output of the electric system is considerably superior. The machine described by the Author has closed, for weeks and weeks, 1,500 rivets per day of 10 hours, requiring the attendance of only three men and a boy. In the machine there is one heavy disk which is always rotating. This disk may at any moment be made an electromagnetic coupling, by which a second disk keyed on to a screw-spindle may be rotated. The screw-spindle moves a large nut at the end of a toggle-joint, which raises and lowers the die for making the rivet-head. There is an automatic cut-out arrangement by means of which the two disks may be disconnected before the end of the travel of the nut. The energy of the second disk is then utilized to finish the rivet. The screw-spindle is four-threaded, the pressure of 50 tons put on the rivet-head is ample to make the machine reverse automatically; that is, after the rivet-head is closed the nut returns again to its original position to be ready for the next stroke. It is indifferent whether two, three, or four thicknesses of the plate be put between the dies, and no adjustment is necessary for different thicknesses.

A. S.

Stanley Steam-Carriage.

(Automotor Journal, vol. iv., May, 1900, pp. 387–390.)

A description of the lighter type of American steam carriages. The boiler is of copper with steel ends and is 18 inches high; 298 $\frac{7}{16}$-inch tubes, $\frac{1}{16}$-inch thick, are expanded into the boiler ends. Piano steel wire is wound round the copper boiler and lagging is provided outside this wire. The furnace consists of 2,500 jets and is fed with petroleum at a pressure of about 35 lbs. per square inch; the petroleum feed is controlled by an automatic valve

actuated by the steam pressure, and is heated, before reaching the burners, by being passed through a pipe which is carried through two of the boiler-tubes. The working pressure is 160 lbs. per square inch; at this pressure the steam cuts off the fuel supply to the furnace. The engine is light, is fitted with ball-bearings throughout, has two double-acting cylinders ($2\frac{1}{2}$-inch bore by $3\frac{1}{2}$-inch stroke) and develops about 4 HP. The transmission gear consists of a single ($\frac{3}{8}$-inch) chain drive, from the engine shaft to the differential gear on the "live" back axle, and provides for a car-speed of 10 miles per hour when the engine is running at 400 revolutions per minute. Water is fed to the boiler by a force-pump driven by the engine. The driver regulates the water-feed by a by-pass on the pump, in accordance with the showing of a water-gauge. The car weighs about $4\frac{1}{2}$ cwt. Drawings are given of a larger vehicle of the same type.

A. G. N.

Electrical Ignition for Gas Engines. P. P. Nungesser.

(Electrical World and Engineer, vol. xxxv., April 7, 1900, pp. 510–511.)

Reliable electric igniters, that combine durability with simplicity of construction, have met with the greatest success in the hands of the average operator. Electrical igniting devices consist of two classes: primary and secondary. Primary igniters, by far the most largely used, are made in three forms: (1) The striking or "make-and-break" contact employs a movable point, operated by mechanism outside the cylinder to strike the stationary point, and can be adjusted to produce ignition at that part of the stroke which gives the highest efficiency with the given combustible mixture. (2) The rotary or wipe spark igniter, which has great wear in the sliding contacts and requires frequent attention to keep it in order. This form gives, with the same consumption of battery power, a much larger spark than the striking or make-and-break igniter. (3) The make-and-break inside igniter, which has the movable part attached to the piston, and separated from the insulated stationary rod by the forward movement of the piston, thereby igniting the mixture.

In the second class, known as jump spark electrical igniters, there is an insulated plug through which pass the wires from an induction or secondary coil to points in the combustion chamber, $\frac{1}{8}$ inch to $\frac{5}{16}$ inch apart. The spark passes through this air space when the primary or battery circuit is closed.

Experience on automobile and yacht engines has shown that a battery having $4\frac{1}{2}$ volts to 6 volts is required with low internal resistance to give 8 amperes to 16 amperes. Waste of current is prevented by having the spark coils of suitable impedance, which may double the life of the battery. Instead of the old style long coils, a

primary coil best suited for high-speed engines, such as used on automobiles, should not exceed 6 inches in length overall, made of annealed Swedish iron, reannealed after cutting, in order to be magnetized and demagnetized rapidly. This shortens the time the circuit has to remain closed, and gives economy in battery power.

Spark coils must be thoroughly waterproof for good insulation. A dry battery is sometimes used for starting an engine where a dynamo or magneto-generator, driven by the engine, gives ignition until the speed is reduced. The high speed necessary for these generators produces considerable wear of moving parts.

The writer considers a good portable closed-circuit battery, perfectly sealed or watertight, without paraffin oil, is not only more economical than the dry battery and dynamo combination, but it requires less care in the rough usage of engines on carriages and boats. W. R.

Multiple-Cylinder Engines. E. Lefer.

(L'Éclairage Électrique, vol. xxiii., April 14, 1900, pp. 60–61; Bulletin de la Société d'Encouragement, vol. v., January, 1900, (3) pp. 58–117.)

The Author compares the advantages and disadvantages of expanding steam in more than one cylinder, as compared with expansion in a single cylinder. When steam engines were first employed on a practical scale to drive industrial works the system of expanding the steam in two cylinders was introduced, though the object to be obtained in so doing was not fully appreciated. As the engines in use at that time were beam engines, one of the main reasons put forward was that it gave a more regular turning effort than when a single cylinder was used. It seems, however, looking at the types of engines which followed these, that an effort was made to obtain a wide range of expansion without altering the existing imperfect means of steam distribution.

The Author traces the various stages of development of the compound steam engine up to the time when modern research demonstrated its economy, but thinks that in spite of the labours of modern experimenters the information relating to this type of engine is not very complete. He then refers to the advocacy of quadruple and quintuple expansion by some engineers, based on the assumption that the more the difference of pressure, and consequently the fall of temperature, in each cylinder was reduced, the less became the internal condensation and the consumption of steam; experience, however, does not always bear this out, and usually expanding three times is considered sufficient. He refers to the uncertainty that existed as to the correct ratios of cylinder volumes, which to-day usually vary from 2·6 to 3 for the ratio of the intermediate to HP. cylinder, and thinks that practice has had more to do with determining this ratio than theory.

He then passes on to examine the different methods of utilizing the steam in order to give a minimum consumption per I.HP. To do this he makes use of the same data that he has already employed in a former Paper on single-cylinder engines; but in order to establish a comparison between multiple-cylinder engines and single-cylinder engines, he assumes that the expansion of steam follows Mariotte's law, which is far from being the case in multiple-cylinder engines. Under these conditions he calculates the steam consumption per I.HP. per hour, assuming different values for (1) Ratio of cylinder volumes; (2) cut-off; (3) initial pressure of steam in cylinder; and then compares under these conditions engines on the Woolf system and those with two or three cylinders.

Various Tables are given in the Paper read before the Société d'Encouragement, showing the influence of these several points. If the results for two-cylinder compound engines are examined it will be seen that a diminution of cylinder ratios corresponds (1) To an increase of power developed by the steam in the first cylinder; (2) to a corresponding diminution in the second cylinder; (3) to an increase of the total power developed by the two cylinders; (4) to an increase in the weight of steam condensed in the first cylinder; (5) to a diminution of the weight of steam condensed in the second cylinder; (6) but the total amount of water condensed shows no diminution.

A closer investigation seems to show that cylinder ratios varying between 2 and 4 are best as regards utilization of heat. A consideration of the influence of various points of cut-off shows that for a given cylinder ratio there is a point of cut-off corresponding to a minimum consumption of steam.

In the third part of the Paper the Author discusses a number of diagrams taken on multiple-cylinder engines, and compares the results of this examination with his calculations. He concludes by stating that although it is true that by employing two or more cylinders to expand the steam in, the fall in temperature in each is reduced, and consequently the internal condensation should fall too; yet, on the other hand, the cooling surface in contact with the steam is increased, so that what is gained by decreasing the range of temperature is more than counterbalanced by the increase of surface in contact with steam. It is from this cause that the steam consumption of a compound engine may be higher than that for a single-cylinder engine. He considers that the loss from condensation is largely due to the difficulties of obtaining the best possible steam distribution with a single slide-valve, and it is this that has led to the introduction of improved independent valves on single-cylinder engines.

L. S. R.

Utilization of Schaffhausen Water-Power. A. AMSLER.

(Inst. Elec. Engin. Journ., vol. xxix., pp. 175–184. Discussion, March 1900, pp. 184–191.)

The original installation in which the power from the turbines was transmitted by wire ropes for a distance of 600 metres along the bank of the river is now being replaced by electric transmission. Owing to the wearing and loosening of the pulleys the speed of the turbines had to be reduced from 40 revolutions to 30 revolutions per minute; the average life of the ropes has latterly become less than a year, the expense of renewal being 35 per cent. of the total income.

Francis turbines are to be used, driving alternators at a pressure of 2,000 volts; the power is to be delivered to consumers at a price of 125 francs a year per B.HP. measured at the motor.

In the discussion F. Prášil gave an investigation of the transformer turbine in which part of the water-supply is used to drive a ring of vanes intermediate between the fixed vanes and the motor-wheel; an artificially increased head is thus given to the water passing through the motor-wheel, and the speed of the latter increased. His conclusion is, that transformer turbines would only be suitable for low variable heads and direct coupling.

H. R. C.

Efficiency of Steam Boilers and Surface Condensers.

T. E. STANTON.

(Mechanical Engineers, March, 31, 1900, vol. v., pp. 445–448. Paper read before the Owens College Engineering Society.)

This communication refers to experiments made by the Author which confirm Osborne Reynolds's theory that the rate of transmission of heat between a metal surface and a fluid in contact with it, for a given difference of temperature between the surface and the fluid, is proportional to the quantity of the fluid carried up to the surface in unit of time. The Author's experiments on water show that the rise in temperature of water flowing through a tube, the surface of which is kept at a constant temperature, is practically the same at all velocities above the critical velocity at which eddying motion is established in the tube. The Paper is illustrated by diagrams showing the temperature in a condenser, having a tube surface of 176 square feet when the supply of cooling water is 15·5 lbs. and 25 lbs. respectively per pound of steam. In another diagram the relation between length of tubes and condenser pressure is shown for the three cases of tubes $\frac{3}{8}$ inch, $\frac{5}{8}$ inch, and $\frac{7}{8}$ inch in diameter. The curves clearly

show that the smaller the diameter of the tube the less the effective length need be to produce a given pressure. As an example with a given supply of steam and cooling water, the effective lengths of tube for a pressure of 1·63 pounds per square inch would be proportional to 26·8, 18·2, and 10·0 for tubes of $\frac{7}{8}$, $\frac{5}{8}$, $\frac{3}{8}$, diameter respectively.

A diagram is given, indicating the arrangement of tubes suggested by the results of these experiments for a condenser of high efficiency.

E. C. S.

Cost of Steam Raising. J. Holliday.

(Institution of Electrical Engineers Journal, vol. xxix., pp. 38–61. Discussion January, 1900, pp. 77–117.)

This paper deals with the work of a boiler, regarding steam in the pipes as the manufactured article and fuel as the chief raw material. The evaporation of 1,000 gallons of water is taken as the unit work in the boiler. Starting from B. Donkin's figures that the cost of dust coke per unit evaporative work is only about one-third of that of large Welsh coal, the Author discusses the disadvantages of the low-priced, poorer fuels—difficulty of burning, more boilers required, more labour needed—which weigh against this economy. Measurements extending over a long period (figures are given for the year 1895) were made on a steam-raising plant consisting of nine approximately equal Lancashire boilers working at 60 lbs. pressure; the demand for steam being fairly constant during the 24 hours. All the boilers were hand-fired. In three boilers, "breeze," costing 3*s.* 6*d.* per ton, was burned, forced draught being used; the mean cost of fuel alone per unit was 2*s.* 8¼*d.*, each boiler evaporating 2,700 lbs. of water per hour. The other boilers burned a good South Wales coal without forced draught, the mean cost of fuel alone per unit being 6*s.* 9¾*d.*; evaporation per boiler 3,800 lbs. per hour. Expenses of working, maintenance, insurance, interest, and depreciation come more heavily on the boilers using the poorer fuel than on the others; including these the costs per unit are 7*s.* 3½*d.* and 9*s.* 2*d.* respectively. Very detailed Tables and diagrams are given.

H. R. C.

Otto Gas Engines. L. Marchis.

(Comptes Rendus, March 12, 1900, vol. cxxx., pp. 705–708.)

Theoretical Cycle of a Gas Engine. A. Witz.

(Comptes Rendus, April, 23, 1900, vol. cxxx., pp. 1118–1119.)

Gas Engines. L. Marchis.

(Comptes Rendus, May 7, 1900, vol. cxxx., pp. 1246–1248.)

The efficiency is calculated for a series of operations not perfectly cyclical, which is really as follows, though in the Paper described with less exactness: (1) The explosive mixture is admitted to the cylinder, as it alters volume from 0 to V, at the temperature t and at the pressure p of the atmosphere, which also acts on the outer face of the piston; (2) it is then compressed adiabatically to volume v, attaining thereby the pressure P and temperature T; (3) explosion then occurs adiabatically and isometrically, the pressure and temperature becoming P′ and T′; (4) adiabatic expansion to volume V follows, with fall of pressure and temperature to p' and t'; (5) isometric change till the pressure becomes p next occurs; and (6) the exploded mixture is finally allowed to escape into the atmosphere, the volume of the cylinder being diminished to 0, while the outer face of the piston is again exposed to atmospheric pressure. Operations (2) and (4) at once give $A = k'(T' - t') - k(T - t)$ for the area of the cycle, where k and k' are the isometric specific heats of the mixture before and after explosion, and from operation (3) we have $k'(T' - T) = H$, where H is the heat given out on isometric explosion at T. The efficiency is then $\frac{A}{H}$ [which, expressed in terms of the data, is

$$1 - a^{\kappa' - 1} + \{k'(1 - a^{\kappa'-1}) - k(1 - a^{\kappa-1})\}\frac{T}{H},$$

where $a = \frac{v}{V}$ and $T = ta^{1-\kappa}$, κ and κ' being the ratios of the isopiestic and isometric specific heats of the mixture before and after explosion], and, if we may take κ' and κ as approximately equal, and so $k' = k$, this becomes $\frac{1 - (t' - t)}{(T' - T)}$ [which is independent of H and equal to $1 - a^{\kappa-1}$]. Starting from this result, Marchis adversely criticises the usual theory given for the Otto engine, in which he asserts that the assumption $p' = p$ is made. [The above notation is varied from that of the Paper for greater symmetry.]

Witz denies that the assumption $p' = p$ is made, and states that in the usual theory operation (4) proceeds till the pressure falls to p (the temperature then being t'' and the volume V″),

and that (6) follows, the efficiency then for $k' = k$ becoming $\frac{1 - \kappa (t'' - t)}{(T' - T)}$. [But this value requires the work done to be $k' (T' - t'') - k (T - t) - p (V'' - V)$; does not however condition (6) require the omission of the last of these terms, and give $\frac{1 - (t'' - t)}{(T' - T)}$ for the efficiency?]

Marchis points out that Witz's criticism is off the point, as he considered engines of the Otto type only in which the adiabatic expansions and compressions are not different; that there is nothing like a true cycle in the case of gas engines, and that Witz's formula for the efficiency cannot be general, though given as such. R. E. B.

Electromagnetic Ore Dressing. E. LANGGUTH.

(Zeitschr. Elektrochem., vol. vi., April 5, 1900, pp. 500–506.)

This Paper deals with the principles underlying the magnetic separation and concentration of minerals. The Author explains the action as the result of the respective influence of weight, motion, and less or greater magnetism of the particles of ore. He does not agree with the recently advanced classification of weak and strong magnetic separation. Two main features are to be considered for rational separation: (1) Production of strong magnets with least expenditure of energy; (2) separation of magnetic and non-magnetic products into divergent paths with the least amount of power. Electromagnets are the only important form used at present.

The conditions best suited for utilizing magnetic energy for the purpose of separation are briefly stated to be: (1) Generation of magnetic currents of the least possible potential and the greatest density; (2) the passage of the material to be operated upon at the least distance from the magnetic poles.

Although theoretically simple, these conditions are not brought into effect in the majority of electro-magnetic separators. Very narrow fields are awkward for separation, and, on the other hand, crushing to uniform grains is not easily accomplished.

Theoretically the diameter of the grain need not exceed the width of the field, but actually at least twice the distance is required. Direct contact of the particles of ore with the bare poles is hardly feasible owing to the manner in which the ore has to be conveyed. As the material is attracted with variable intensity by the two poles, actual experiments must decide the exact distance at which it must be passed.

Experiments are then given in which the ratios between motion and magnetism are altered. The apparatus used was the ore separator of the Mecherniche Bergwerks-Aktienvereins. Distance

of poles 7 millimetres, and material passed at variable speed 1 millimetre from active pole working on a belt. Power expended 1 kilowatt, thus ensuring a very concentrated field between the poles. The artificial mixture of material consisted of same sized grains of magnetite (strongly magnetic), rhodonite (medium magnetic), zincblende (feebly magnetic). The results obtained were as follows: (1) Velocity of belt 100 metres per minute, magnetite alone affected. (2) 70 metres per minute, rhodonite partially attracted and zincblende not at all. (3) 50 metres per minute, rhodonite completely separated, but not zincblende. (4) 40 metres, partial action upon zincblende. (5) 30 metres, zincblende entirely attracted. On lowering speed to 5 metres per minute the zincblende could still be magnetised with an expenditure of 20 watts.

The Author therefore draws attention to the importance of adjusting the rate of travel in accordance with magnetic properties. Reference is then made to the problem of material falling vertically in the neighbourhood of a magnet, and the conclusion arrived at is that this method must be wasteful from the point of view of power expenditure unless efficient means are found of suitably diminishing the speed by obstacles. The Author concludes by stating that the conditions underlying the problem of electromagnetic separation are, therefore—(1) Generation of magnetic currents of least intensity and greatest density; (2) passage of the material to be operated upon through the magnetic field uniformly at the least possible distance from the active separative pole; (3) variable external movement of the material under treatment; (4) separation in homogeneous magnetic fields.

O. J. S.

Liquid Fuel. H. Guérin.

(Génie Civil, vol. xxxvii., May 12 and 19, 1900, pp. 22–25 and 36–39.)

This subject has recently come afresh before the French Society of Civil Engineers with special reference to the establishment of supply stations for ships of war. Evidence exists of the increased use of liquid fuel in British vessels trading to the Far East, the installation of a charging station at Suez having been authorized by the Egyptian Government, and for railway and other purposes in Russia, America, and other countries. The Author refers to articles in vols. xxxiv., xx., xxiv., viii., xxi., xxxv. and xxxvi. of the *Génie Civil*, and to a Paper in the *Engineering and Mining Journal* of New York, by H. Tweddle, which describes the best methods of using this fuel and of which this article is to some extent a *résumé*. The best results have been obtained by the use of crude petroleum.

The proportions of carbon, hydrogen, and oxygen in various

hydrocarbons and their calorific power (in calories per kilogram) are given in the following Table:—

—	C.	H.	O.	Calorific Power.
Light petroleum oil—American	86·894	13·107	..	10,913
Refined	85·491	14·216	0·293	11,047
Petroleum spirit	80·583	15·101	4·316	11,086
Crude petroleum	83·012	13·889	3·099	11,094
Light oil from Baku	86·700	12·944	..	10,843
Petroleum from the Caucasus .	84·906	11·636	..	10,328
Ozokerite from Boryslaw . .	83·510	14·440	..	11,163

To realize the theoretical calorific power and the highest temperature of combustion it is necessary to supply to the combustible the exact quantity of air furnishing the necessary amount of oxygen, and to have the most intimate possible contact between the air and the fuel. Consequently gaseous fuel offers the best conditions for obtaining the best result, liquid fuel the next, and powdered solid fuel the next in order, although in practice excess of air, deposits of soot and other causes prevent more than a moiety of the useful effect being realized, especially in the case of coal firing. The methods of using fuel in the liquid form are, however, the most simple of all, and hence the repeated efforts towards a more general introduction of this kind of fuel.

Various forms of injectors or "pulverizers," which have been from time to time proposed and introduced, are enumerated by the Author, and the effects of different forms of jets on the completeness of the pulverization of the oil and its admixture with the air are discussed. The most suitable form of flame for a given furnace or process depends upon the quality of the oil and on the purpose to which the heat of combustion is to be applied.

Tweddle has found by experiment that in order to obtain the highest possible temperature from liquid fuel it is necessary to burn it in fire-brick combustion chambers of limited capacity, and that for evaporative effects an injector worked by steam is preferable to one using an air-jet, which is more suitable for reheating, forge, and other furnaces of that class. The Author introduced the use of petroleum fuel on the Oroya Railway in Peru in the year 1890, where experiments had to be conducted under unfavourable conditions. Starting from sea-level at Callao, the railway crosses the Andes at an altitude of 4,250 metres, with a total length of about 160 kilometres. The gradients and curves are consequently against the realization of a high duty. Nevertheless, the consumption of oil was little over half that of coal for the same work, although the calorific power of the oil as compared with that of coal was only as 1·4 is to 1.

The apparatus used on this railway is described in detail with illustrations of the burner, or pulverizer, and of the type of furnace employed.

The evaporative effect produced by firing boilers with American petroleum was in 1896 found by the Weyher and Richemund Company to be 12·5 lbs. of water per lb. of fuel; at the power station of the electric tramways of Los Angelos it was 12·89 lbs.; and in other experiments, with Borneo petroleum, 758 grammes of oil produced the same results per HP. hour as 1,030 grammes of Newcastle coal. At the last Exhibition in Chicago the steam boilers, working at about 125 lbs. per square inch pressure of steam, gave with mineral oil fuel an evaporation of 14·25 lbs. of water per lb. of combustible as against 7 lbs. per lb. of coal. The theoretical evaporative power of carbon burning to carbon dioxide is 15 lbs. of water at boiling-point under atmospheric pressure.

In steamships it is necessary to use heavy oils igniting at 121° C. to 149° C. in order to guard against the risk of fire, these oils being quite safe even if a bar of red-hot iron be plunged into them. Experiments made by the French Government on the use of petroleum in torpedo-boats proved that it is too dangerous for use in such vessels.

Tweddle made experiments by firing cannon-balls and shells into a pile of casks containing benzene, with the result that the flame from the exploding shell frequently set fire to the benzene vapour. Practically the same effects were produced with kerosene and crude petroleum, but with oil igniting at 115° C. no flame was produced even under much more severe tests. If the oil employed has a sufficiently high point of ignition it offers greater security from fire than coal and much more than powdered fuel in bulk, both under the conditions of warfare and under ordinary conditions in which spontaneous combustion sometimes occurs.

The handling and storage of liquid fuel are also a much more easy matter than is the case with coal; the necessary appliances are fewer and more simple, and the minimum of labour is all that is required. There are also other minor advantages, not the least of which is the saving of space on board ship of storage of fuel.

In furnaces used in the industrial arts some of its advantages may be realized, where a high temperature and a pure flame are desired and when the price of coal is high. The Author gives some illustrations of such furnaces, and, in particular, of one designed by Tweddle for the combustion of benzene.

F. J. R.

Electric Annealing of Armour-plate. C. J. Dougherty.

(Eng. Club Phil., Proceedings, vol. xvii., pp. 12–22; Discussion, February, 1900, pp. 22–23.)

The Author begins by explaining the disadvantages of having to bore the holes in armour-plates before hardening them by the Harvey or Krupp processes, and mentions sundry abortive attempts which have been made to obviate the difficulty. He then proceeds

to explain the method devised by the Thomson Electric Welding Company, of Lynn, Mass., and the apparatus utilized for the purpose of locally softening the steel by means of the intense heat of a very heavy current. The current is generated at 300 volts, and the maximum employed is 100 amperes. It is transformed down to from 2·5 to 2·8 volts, and at the maximum 10,000 amperes are passed. The current is introduced by special water-cooled copper contacts and a current density of as much as 40,000 amperes per square inch is employed where these touch the surface of the plate, but so effective is the water-cooling that the leads do not suffer at all. The current has to be turned on gradually by means of a resistance, and must not be switched off suddenly, or the softening is not effected. The operation takes from fifteen to twenty minutes. Illustrations and diagrams are given.

J. L. F. V.

Theory of the Welsbach Burner. W. Nernst and E. Bose.

(Phys. Zeitschr., vol. i., March 31, 1900, pp. 289–291.)

That the temperature of a platinum wire when brought into a Bunsen flame is the higher the finer the wire, is not due to conduction, as shown by the fact that coils of thick platinum wire have the same low luminosity as simple loops. The temperature attained by the foreign body is the higher the quicker the heat is supplied to it, and the less the heat radiated by it. Carbon particles obey the laws of radiation of black bodies, and therefore emit infra-red heat rays to a great extent. A substance whose radiation was confined to the visible spectrum would be the ideal incandescent substance. It is probable that magnesium closely approaches this ideal state. The mantel of the Welsbach (Auer) burner also comes near it. By tracing the luminosity of the spectrum in terms of a normal incandescent lamp, and drawing the luminosity curves for incandescent lamps at various efficiencies and for the arc, a series of curves may be obtained which represent the radiation of carbon at various temperatures. The curve of the Welsbach burner shows a considerable falling off in the red portion, and, therefore, probably also in the infra-red region, when compared with the radiation of carbon. This means that much of the energy otherwise wasted in heat is utilized for increasing the luminosity, and this fact, together with the rapid acquisition of the temperature of the flame, accounts for the economy of the Welsbach incandescent light.

E. E. F.

Standards of Light. J. E. Petavel.

(Proceedings of the Royal Society, vol. lxv., January, 1900, pp. 469–503.)

Various classes of standards of light are described by the Author which belong to the two main divisions: (1) Flame standards, and (2) Incandescent standards. He considers at some length the arc light standard, and concludes that the intrinsic brilliancy of the crater of a silent arc is about 147 candle-power per square millimetre; and that even when the most favourable conditions are selected, and the intensity of current and the length of the arc are maintained constant, it is difficult to obtain consistent results, variations of over 5 per cent. being by no means unfrequent. The crater of the arc does not, therefore, possess the qualities required of a standard. Incidentally the experiments made confirm the theory that the crater of the arc is at the temperature of volatilization of carbon.

The Author next describes and considers the Lummer and Kurlbaum incandescent platinum standard, and then gives an account of researches on the molten platinum standard of light. The methods of fusing platinum by the electric current, and by the oxy-hydrogen blow-pipe, are described. To ensure suitable conditions and a pure surface (1) the platinum must be chemically pure, (2) the crucible must be made of pure lime, (3) the hydrogen burned must contain no hydrocarbons, and (4) the gases should be burnt in the ratio of four volumes of hydrogen to three of oxygen. A large number of observations extending over a long period of time were made. It was found that the effect of contaminating the platinum with either silica or carbon was very marked. From the results of his work the Author states that the probable variation in the light emitted by molten platinum under standard conditions is not above 1 per cent., and the accuracy of this standard is capable of being increased. Physiological considerations fix a limit to the accuracy of photometric observations. It is not impossible that the accuracy of the platinum standard may attain to or even surpass this limit.

J. J. S.

Temperature of the Acetylene Flame. E. L. Nichols.

(Physical Review, vol. x., April, 1900, pp. 234–252. Paper read before the American Physical Society, February 24, 1900.)

The Author gives the results of experiments made to determine the temperatures at different points of an acetylene flame, for which various observers have given widely different numbers; thus Le Chatelier gave 2,100–2,420°, whilst Lewes found a maximum temperature of 1,517°, Smithell's values being intermediate between

these two. The flame employed by the Author is of the usual flat type, the burner being capable of lateral motion by means of a micrometer screw. The thermo-electric couples are composed of platinum and platinum-rhodium (10 per cent.) wires, of thickness varying from 0·01996 to 0·00821 centimetre; the ends of the wires are pinched together in the form of a V, the point of which is fused by plunging into an oxy-hydrogen flame, and then cut off so as to leave a connection about 0·005 centimetre thick. The electromotive force produced at the heated junction is measured by a potentiometer and Clark cell. To observe the acetylene flame, and to measure the distance between its median plane and the thermo-element, a magnified image is obtained on the ground glass of a micro-camera, the plane of the flame being arranged parallel to the axis of the camera. The thermo-junction is placed at a distance of 6 millimetres from the median plane, and the temperature taken by balancing the potentiometer, the junction then being gradually brought up to the middle of the flame, the temperature at each new position being determined. With each of the four couples used, the temperature is found to increase gradually at first, but at a distance of about 0·4 centimetre from the middle the curve suddenly becomes steep, so that this distance probably measures the thickness of the layer of non-luminous gas surrounding the well-defined luminous layer, which has a thickness of about 0·065 centimetre. Before this luminous layer is reached, the temperature curve shows signs of approaching a maximum, the thicker junctions (0·01996 and 0·01598 centimetre diameter) being coated with carbon and considerably cooled when coming into contact with the luminous region. The thinner couples give temperature curves lying above those of the thicker ones, and give no deposit of carbon, but are melted in the middle portion of the flame, one of them after passing the median plane and the other before that plane is reached. By extrapolation the temperatures at various parts of the flame for a thermo-junction of negligible cross-section can be estimated; by this means the temperature at the middle of the flame is found to be 1,900°, whilst at 1 millimetre from the middle the value is 1,920°. Similar experiments with a luminous coal-gas flame indicate its highest temperature to be 1,780°, the value for a candle flame being 1,670°. The fact that a thin platinum wire—prepared by Wollaston's method of silver-plating it, then repeatedly drawing through a die to diminish its diameter and finally dissolving away the silver—can be melted in a candle flame, the Author shows is due to the presence of impurities in the wire which make it melt at 1,674°, whilst pure platinum melts at 1,775°. The temperatures given by the Author are based on an arbitrary scale in which the melting-point of platinum is taken as 1,775°, and that of gold as 1,070°.

T. H. P.

Powerful High-frequency Currents. d'Arsonval.

(Comptes Rendus, vol. cxxx., April 17, 1900, pp. 1049–1054.)

A description of arrangements employed by the Author in the decoration of the façade of the Palace of Electricity at the Paris Exhibition of 1900. Highly luminous and very brilliant sparks were required, some to be short and others much longer. To produce these the discharge of powerful condensers has been employed, these latter being charged by transformers at high potential actuated by alternators. A description is given of the transformer, condenser, exploder, and transforming coil. The transformer is of the Labour type with closed magnetic circuit. It can absorb up to 30 kilowatts. The condenser, after trial of many substances, was finally made with micanite as insulating material, with sheets of tin plate. The micanite is formed by gluing together when hot, with gum lac and under high pressure, very thin sheets of mica. The whole is plunged in a glass vessel containing ordinary petroleum, which acts as an excellent insulator. The condenser thus formed behaves admirably: there is no heating, as there is no electrolysible substance. The discharge spark of the condenser takes place between two balls. A continuous arc is formed which can be blown aside by a magnetic field, but preferably by a jet of air. The rotatory exploder has been devised to get a convenient means of blowing the spark. Two metallic rods with spheres at their ends are made to rotate rapidly, describing in air a circumference whose diameter varies in different cases from 30 centimetres to 200 centimetres and more. Thus a strong wind is produced between the balls simply by their displacement in air with an insignificant expenditure of energy. When in these circumstances the spark passes a very interesting luminous phenomenon is produced; the effects resembling those obtained with a revolving mirror, but being much more luminous. The Author's transforming coil, by which the long sparks required are obtained, is next described. The arrangement is similar to that used by Elihu Thomson. The induced and inducing circuits are concentric and immersed in a vessel of oil. Long and brilliant sparks are obtained, and the length can be increased several times by making them pass to plates of marble covered with thin sheets of metal, preferably zinc. J. J. S.

Electrolysis by Earth Returns in Chicago. E. B. Ellicott.

(Western Electrician, vol. xxvi., February 10, 1900, p. 87.)

Within the last two years many cities have experienced serious troubles from the bursting of water-mains, and in nearly every instance the primary cause of the bursting was due to the deteriorating effect of the return current from a street railway. Some of

the conditions in Chicago are especially bad, and no effort seems to be made by the companies to make such corrections as may be in their power. The situation is now such that nothing but a combined effort of all companies will clear up the dangerous conditions and relieve the companies of a liability that will surely be placed upon them by the courts.

It is the practice in street-railway work to bury under the rails a large amount of copper wire, and at points varying from 25 feet to 1,000 feet apart, to connect this wire to the rails with copper connecting wires. The importance of good bonding and connecting is illustrated by an example in Chicago, where the drop in potential in one mile of track and supplemental copper-return wire was 8½ volts. After three bad bonds had been replaced, a drop of only 2½ volts was shown. A water-pipe ran parallel to the track for a considerable distance, and, before the change in bonds, it was found to be 1 volt positive to the rails at two places. After the change in bonds the potential between the rails and water-pipes was about $\frac{1}{30}$ of a volt at all points.

After a careful study for over two years, the Author has recommended a clause to be inserted in an ordinance recently passed by the council, requiring the railway company to provide and maintain a return circuit of such conductivity that the maximum potential between any part of the return circuit and the water-pipes should not exceed one volt, and also providing that there should not be a variation in potential of more than one-half volt between any two points within a distance of 300 feet, measuring along the line of the railway. Under these conditions there will be some flow of current to and from the water-pipes, but with the one-half volt variation the disintegrating effect will be distributed over a large area of water-pipe. The Author maintains that the only excuse for using a grounded return circuit is the question of economy in construction and maintenance.

E. K. S.

Electrolysis by Earth Returns. A. A. Knudson.

(American Electrician, vol. xii., March, 1900, pp. 119–120.)

The Author is of opinion that the independent return is not the absolute cure for electrolysis which some believe it to be. He has measured a number of joints in water-mains, and generally found their resistance to be proportional to the length of time they have been in the ground; thus, in some tests on 27 joints on 4-inch and 6-inch pipes it was found that in 11 months some had doubled, some trebled in resistance, whilst others had increased as much as 60 times. Before ordinary water-pipe lengths are laid they are treated with asphalt varnish inside and out, and when laid together lead is run in. Now if in the caulking process the lead touches the iron in any place galvanic action is set up, and this,

added to ordinary corrosive effects, causes the resistance of the joint to increase year by year. The effect of such resistance causes any current which may be passing along the water-pipes to leave the positive end of the pipe and pass through the earth around the joint, to the end of the next length, or the current may pass through the water in the pipe and cause electrolytic pittings inside. The Author is of opinion that pipes which have been underground five years or longer should not be connected with street railway systems. In other words, the older the water-pipe the less able it is to carry current without damage to itself. In criticising another suggestion, viz., to use a generator of low voltage at the power-station to lower the potential of the piping, the Author says that any method which compels the water-pipes of a city to act as a return conductor for railroad circuits is wrong in principle to begin with, and detrimental to the piping system in the long run. If water- and gas-mains were continuous conductors, like lead-sheathed cables having no joints, then the problem would be less difficult. Seeing, however, that things are as they are, there is nothing in sight as an absolute cure for electrolysis except to abandon the earth, as the telephone companies had to do when the overhead trolley came in. This means double-overhead or underground systems, and it may be mentioned that the former has been adopted on Cincinnati and on some of the Washington lines.

E. K. S.

Insulation Tests. W. E. Ayrton and T. Mather.

(Philosophical Magazine, April, 1900, vol. xlix., pp. 343–347.)

The guard-wire as originally arranged by W. A. Price was applied near the ends of the cable under test; it was intended to eliminate errors due to end leakage. The Authors now use the guard-wire to eliminate leakages of all kinds from the leads. A concentric cable is employed as the lead, the "inner" conductor of which is connected to the conductor of the cable under test, while the "outer" acts as a continuous guard-wire. The "outer" is connected to some point between the battery and galvanometer. It is shown that the guard-wire principle can further be applied to determine whether a cable is faulty throughout, or whether it contains one or more faults in definite positions. Also, by employing two drums, faults in braided and other unsheathed cables can be localised by the use of a guard-wire. In making measurements with the guard-wire, it should be connected as near the braiding as is consistent with the condition that the resistance between the guard-wire and braiding is high compared to the battery resistance. The above remarks refer to the direct-deflection method, but the Authors show that accuracy can also be obtained with the "loss of charge" method, by the use of a guard-wire. In this

case the potential of the guard-wire is caused to fall at the same rate as that of the conductor of the cable under test, so that no electricity passes between them, and there is no surface leakage.

R. A.

Slip-ring and Commutator Losses. G. DETTMAR.

(Elektrotechnische Zeitschrift, vol. xxi., May 31, 1900, pp. 429–436.)

The main object of this Paper is to establish rules for the best sizes of brushes. The losses occurring with carbon brushes, which are gradually superseding copper ones, are considerably higher than when these latter are used. The subject of slip-rings is considered first. Curves are given showing the variation of the contact resistivity (*i.e.*, the resistance per square centimetre of contact area) with peripheral speed for various currents, its variation with current for various speeds, and its variation with pressure for a given current, for both copper and carbon brushes. These curves clearly bring out the following points: (1) The change of contact resistivity with speed is dependent to an extraordinary degree on the material of which the brushes are made; in all cases there is a rapid initial increase of resistivity as the machine starts from rest; with copper gauze brushes the resistivity becomes practically constant beyond a speed of 1 metre per second. With brushes of sheet copper the resistivity reaches a maximum, and then decreases with further increase of speed; with brushes of sheet brass there is a steady increase of resistivity within all ordinary limits of speed; lastly, carbon brushes give results similar to those obtained with copper gauze brushes. (2) The contact resistivity always decreases with increasing current density, although the exact law connecting these two quantities depends on the material of the brushes. (3) The contact resistivity steadily decreases with increase of pressure. Since the electrical loss at the surface of contact decreases, while the friction loss increases, with increase of mechanical pressure, it follows that for a given current density there will be a certain value of the pressure which gives the least total loss. The Author finds that under average conditions a pressure of 125 grammes per square centimetre for copper gauze, and 140 grammes for carbon brushes, gives the best results. It is next shown that, assuming the above values of the pressure, it is best with copper gauze brushes to use as high a current density as possible, while in the case of carbon brushes the best area of contact is given by the formula:—

$$S = \frac{I}{3 \cdot 79 \sqrt{v}}$$

where S is the total surface of contact of the brush in square

centimetres; I the current, and v the peripheral velocity, in metres per second.

The Author next deals with commutators, where the presence of insulation between the segments introduces a complication. Curves are given similar to those described above for slip-rings. The curves show that, for both copper and carbon brushes, the contact resistivity steadily decreases with increase of current density, and that for a given pressure and given current density it becomes, after a rapid initial rise, practically independent of the speed beyond a value of 2 metres per second. This latter result is in direct opposition to those obtained by Arnold, but the Author has proved experimentally that if the commutator is even slightly out of truth, the resistivity passes through a maximum as the speed is increased. With copper brushes it is best to work with the highest permissible current density and the least permissible pressure; while in the case of carbon brushes, assuming a pressure of 149 grammes per square centimetre, the best contact area is given by—

$$S = \frac{I}{0 \cdot 9 + 0 \cdot 71 v}$$

The last section of the Paper deals with the rise of temperature.

A. H.

Friction Losses in Induction Motors. F. BLANC.

(Elektrotechnische Zeitschrift, vol. xxi., February 15, 1900, pp. 131–133.)

Referring to Braun's article on this subject,[1] the Author states that the only unsatisfactory feature about method (4) is the fact that the experimental determination of N/N_o is very laborious if accuracy is required. He then describes the following method of finding the friction loss (this method being, however, only applicable to motors provided with slip-rings). Let w_c = copper loss, in watts, in rotor windings when the motor is loaded, w'_c = ditto when running light; w = power, in watts, employed in turning rotor; σ_o and σ = slip of rotor, expressed as fraction of synchronous speed, when the motor is running light and loaded respectively. Then we have—

$$\frac{w_c}{w} = \frac{\sigma}{1 - \sigma}.$$

Now when the motor is running light, w becomes w_f, the friction loss. Hence—

$$w_f = w'_c \frac{\sigma_o}{1 - \sigma_o},$$

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[1] Science Abstracts, 1900, No. 349.

and it remains to determine w'_c and σ_o. Since the frequency of the rotor currents is very low, the reactance of its windings may be neglected, and w'_c calculated from the formula $\frac{E^2}{R}$, where E is the electromotive force induced in the rotor windings, and R their resistance. If E_o stand for the electromotive force induced in the open-circuited rotor winding between two slip-rings when the rotor is standing still, then the electromotive force in the same portion of the rotor winding when the rotor is running with a slip σ_o is $E_o\sigma_o$. From this it follows that if R_2 and R_3 denote the resistances of one phase of a two-phase and three-phase motor respectively—

$$w'_c = \frac{2\,E^2_o\sigma^2_o}{R_2} \text{ for a two-phase motor,}$$

and—

$$w'_c = \frac{E^2_o\sigma_o}{R_3} \text{ for a three-phase motor.}$$

In order to find σ_o, the Author recommends the following extremely simple and at the same time accurate method. A small magnetic needle (a charm-compass is very suitable for this purpose) is brought near one of the conductors connecting the rotor windings to the starting resistance. The number of oscillations of the needle then gives the frequency of the rotor currents and therefore the slip. In dealing with single-phase motors, $E_o\sigma_o$ in the formulas for w'_c must be replaced by $0 \cdot 9\ E_o\sigma_o$. In conclusion, the Author gives the following formula for the friction loss, and states that it has been found applicable to motors from $\frac{1}{10}$ to 300 HP.:—

$$w_f = C\sqrt{H.P. \times D},$$

where D is the rotor diameter in centimetres, and C is a constant depending on the construction of the bearings and ranging from 20 to 30.

A. H.

Alternating-Current Motors. W. A. Layman.

(Mechanical Engineer, vol. v., January 20 and 27, 1900, pp. 80–82 and 128–130, and February 3, 1900, pp. 170–172. Paper read before the Engineers' Club of St. Louis, and reprinted in the "Journal of the Association of Engineering Societies.")

After giving a description of induction motors in general, the Author proceeds to describe in detail one manufactured by the Wagner Electric Manufacturing Company of St. Louis, for which a large starting torque is claimed. In these machines the armature cores are wound with an ordinary direct-current progressive winding, connected up to a commutator in exactly the same fashion as in the direct-current motor winding. The commutator

of this armature is so designed that it may be completely short-circuited by introducing a short-circuiting circle of copper segments. When so short-circuited, this winding differs from the squirrel cage only in that, instead of the currents being left to select paths for themselves, they are restricted to flowing in paths afforded by the individual coils of the armature winding. The commutator is of the radial type. The short-circuiting band is made up of small copper links, which, being mounted upon a

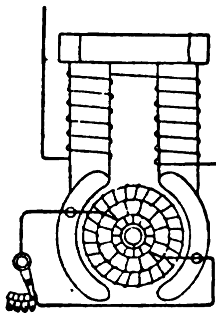


FIG. 1.

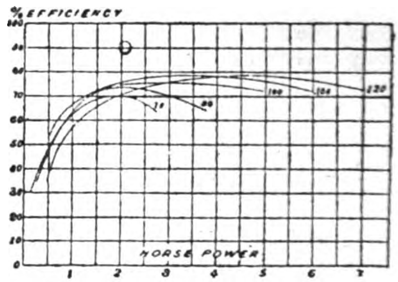


FIG. 3.

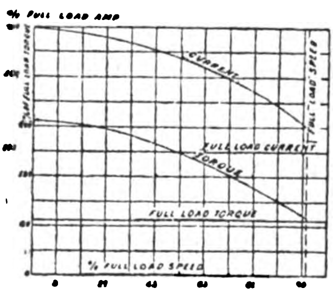


FIG. 2.

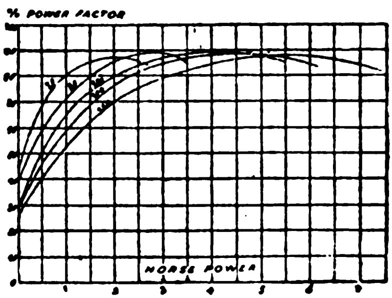


FIG. 4.

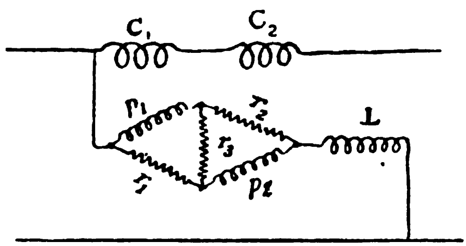
short-circuiting ring, are thrown into an angular opening in the commutator, and by making close contact with each segment it short-circuits the whole armature. The starting arrangement is shown in *Fig. 1*, which shows a starting resistance placed between brushes rubbing on the commutator. *Figs. 2, 3, 4*, show respectively the relations between starting torque and current, efficiency and load, and power factor and load.

W. G. R.

Alternate-Current Meters with Rotary Field.

(Elekt. Runds., vol. xvii., April 1, 1900, pp. 131–132.)

In meters of this description two adjustments are necessary; first, a phase-adjustment for the shunt circuit, whereby the field of this circuit is brought exactly into quadrature with the impressed P.D.; and secondly, an adjustment for varying the field intensity so as to enable the instrument to be made direct reading. Altering one of these adjustments generally upsets the other, so that the final adjustment can only be obtained satisfactorily after a good deal of trouble. In order to avoid this difficulty Siemens



and Halske have recently introduced the method of connection shown in the accompanying diagram, in which C_1 and C_2 are the main or current coils, and p_1, p_2 the pressure coils, producing a field which is in quadrature with the main field. The phase-adjustment is obtained by varying the non-inductive resistance r_3, and the intensity-adjustment by varying simultaneously the two equal resistances r_1 and r_2; L being a reactance-coil which is joined in series with the Wheatstone-bridge arrangement of the shunt circuit.

A. H.

Siemens and Halske Three-phase Generating Set at the Paris Exhibition.

(Elektrotechnische Zeitschrift, vol. xxi., May 3, 1900, pp. 344–346.)

The machine is direct-coupled to a Borsig vertical engine, and the full load output is 2,000 kilowatts at 2,200 volts, 50 periods at 83·5 revolutions per minute. The poles are laminated; the field-magnet system forms the flywheel of the engine, and is mounted on a separate shaft with two bearings. The field copper is wound on edge, and its cross-section is 4 millimetres × 23 millimetres. Cross-sections are given, showing the construction of the armature and the cast-iron ring, &c. The armature conductors have a cross-section of 7 millimetres × 44 millimetres, and are arranged

in 648 slots, each 13 millimetres × 55 millimetres, lined with micanite. The exciter is mounted direct on the alternator shaft; it is an eight-pole machine, and gives 45 kilowatts at 210 volts.

E. K. S.

Transformers at Niagara.

(Electrical World and Engineer, vol. xxxv., February 10, 1900, pp. 227–228.)

A description of a set of 1875 kilowatts Westinghouse oil-insulated transformers, which are the largest hitherto made. They are used for transforming from 2,200 volts two-phase to 11,000 volts three-phase by Scott's method. Each measures 9 feet high by 7 feet in diameter, and weighs 30,000 lbs. including oil. The efficiency at full load is 98·5 per cent., at quarter load 97·6 per cent., and at one-tenth load 94·6 per cent.; the iron loss being 0·54 per cent., and the full load copper loss 0·96 per cent. The secondary drop at full non-inductive load is only 1 per cent. The 13 per cent. reduction in voltage required for the secondary of one transformer of a Scott-connected pair is obtained by cutting in more turns in the primary; and in a similar way the 5 per cent. adjustment in secondary voltage, necessary for regulating with different loads, is conveniently carried out.

W. H. E.

Rotary Converters. H. S. Meyer.

(Elektrotechnische Zeitschrift, vol. xxi., April 5, 1900, pp. 267–269. Translated in Electrical Engineers, vol. xxv., May 4, 1900, pp. 618–620.)

The Author briefly discusses the uses of rotary converters, and considers the various methods of excitation. The shunt winding is suitable where special arrangements are provided for regulating the P.D. at the ends of the various feeders on the continuous-current side. More commonly, however, the compound winding is used, by means of which an increase of the terminal P.D. may be obtained with an increase of load. This effect is brought about by the varying phase-displacement of the current relatively to the P.D. With light loads the current should be a lagging one, and with heavy loads a leading one. Between the converter terminals and the three-phase supply mains are inserted suitable choking coils, by the action of which a leading current causes a rise of P.D. across the converter terminals, while a lagging current causes a fall of P.D. Frequently the line itself has a sufficient amount of inductance to provide the necessary regulation, and then the choking coils may be dispensed with. It is to be noted that an increase in the excitation *per se* is unable to cause any

change in the P.D., for the ratio of the continuous to the alternating P.D. is perfectly definite, and, though slightly variable with the load, is independent of the excitation. A third method of excitation consists in omitting the field winding entirely, so that the excitation is furnished by the armature current. On account of the extremely heavy wattless currents, and consequent low power-factor, this form of converter can hardly be expected to find any application in practice, except in cases where cheapness of construction is of paramount importance. The Author finally deals with inverted rotaries. In order to prevent racing, these machines should be over-excited and furnished with centrifugal regulators for cutting off the supply of current when the speed exceeds a certain limit.

A. H.

Power Transmission with Constant Current.

H. Cuénod and R. Thury.

(Soc. Int. Élect., Bull., vol. xvii., January, 1900, pp. 9–93.)

This Paper describes the Thury system, and includes an account of installations where it is employed. The aggregate capacity of the plant installed since 1893 amounts to 17,500 HP., including a 5,000-HP., 22,000-volt plant, now under construction, to supply Lausanne from St. Maurice, 56 kilometres distant, where water power is to be taken from the Rhone.

The power is generated in each case by a number of direct-current dynamos connected in series according to the voltage required, and giving a constant current. The motors to be worked in the circuit are all designed to take the same current, the voltage of each depending on its output. The maximum voltage of each dynamo varies in different cases from 1,000 to 3,500, and the greatest current hitherto used is 250 amperes. The dynamos are mostly drum-wound, six-pole, and are in some cases excited independently. No trouble is experienced from sparking on the commutator, the number of segments being such that the voltage between adjacent segments does not exceed 15, in machines for the higher pressures.

When the engine or turbine is to run at a fixed speed, and the dynamos are self-excited, the current is automatically kept constant by a regulator which, between full and three-quarter voltage, shunts the field, and for lower voltages moves the brushes. If separate excitation is employed, the exciter is driven by its own turbine, whose speed is automatically adjusted by the main current. Usually, however, the engine is arranged to run at a variable speed, giving a constant torque; the opposing torque varies nearly as the square of the current, and hence the current remains

nearly constant. With turbines the applied torque varies with the speed, and therefore the self-regulation is not so exact. But, in either case, occasional hand-regulation is sufficient; or the control may be automatic, *e.g.*, by means of a series motor carrying the main current, whose armature, resisted by a yielding spring, actuates the valves of the turbines.

Motors have their speed automatically controlled by one or more of three methods:—

(1) Regulating the field; either by a resistance in shunt or by changing the field connections so as to put some of the windings in opposition to the others. (The latter principle can be used for reversing if required.) This is the method most used, but it is not suitable for motors of over 100 HP., owing to sparking at the brushes.

(2) Changing the position of the brushes.

(3) Using secondary cells in shunt with the brushes. This method is employed only for motors under 10 HP. or 15 HP., preferably compound-wound. When the load is light the cells are changed, the torque being thus increased and the speed kept down. The energy stored can be used at times of heavy load.

In case of excessive speed the motor is short-circuited by a centrifugal device; and if the terminal voltage becomes too great (*e.g.*, by a break in the circuit) an electro-magnetic by-pass comes into action. As a protection against a very sudden rise in voltage, such as sometimes arises from atmospheric "circulatory discharges," a lightning-arrester is connected across the poles, in addition to the two between poles and earth.

The efficiency of a 300-HP. motor was found to be 93½ per cent.

Distribution for lighting and for small motors is carried out by means of motor-generators giving constant pressure. In one case the reserve plant includes dynamos which can give either constant current (with separate excitation) or constant pressure (with shunt excitation), and can therefore be used either in the primary or the secondary, as desired.

W. H. E.

Enclosed Fuses. J. Sachs.

(Transactions of the American Institute of Electrical Engineers, vol. xvii., February, 1900, pp. 85–116.)

A fuse should have a definite maximum continuous running current capacity, and blow for a definite overload whether gradually or quickly reached. The fuse advocated has a zinc or aluminium link of wire or strip in a powder containing borax, which will dissolve the oxides, and prevent the formation of a tube full of molten wire. Copper wire is not desirable, because when disrupted it yields a conducting vapour. On short-circuiting a fuse with long break an objectionable arc is prevented by

the sudden disrupting of the fuse, but with slow overloading this may not be the case. An inductance in series with a large fuse diminishes the maximum rush of current but increases the potential of break across the fuse terminals.

M. O'G.

Properties of Carbon in Electrical Work. Elihu Thomson.

(Electrical World and Engineer, vol. xxxv., May 12 and 26, 1900, pp. 703–705 and pp. 787–788. Abstract of a Paper read before the North Eastern Section of the American Chemical Society in Boston.)

The Author deals seriatim with the uses of carbon for various electrical purposes. In the first place the employment of arc-lamp carbons is entered upon, and it is shown that no mixture of carbon with other substances has been successful in replacing the pure carbon. The value of carbon for electrodes for arc-lamps is ascribed to its absolute infusibility and high temperature of sublimation. The latter is said to be, according to Violle, about 3,500° C. Before the volatilization the carbon is converted into pure plumbago, and it is this that gives rise to mushroom growths on the negative carbon when the carbons are too close together.

Reference is made to the Acheson method of making graphite by passing very heavy currents of electricity through artificial carbons embedded in loose carbon. With regard to incandescent lamps, the universal use of carbon filaments is referred to, and the method of preparation and flashing the filaments is explained.

Further, the employment of carbon in telephone transmitters is explained and its advantages discussed. Finally, the introduction of carbon brushes to replace metal ones on continuous-current motors is shown to have been a great boon in motors for traction purposes.

An account of a modified carbon brush, which the Author has had in successful use for over 7,000 hours, is given, and the method of construction is explained.

J. L. F. V.

Cheap Fuels and the Cost of Electrical Energy.

R. E. Crompton.

(Institution of Electrical Engineers Journal, vol. xxix., pp. 62–77. Discussion, January, 1900, pp. 89–117.)

After pointing out that, in many instances, as soon as appliances are arranged to use a cheap fuel systematically, so soon is either the price raised or the supply exhausted, the Author states that there are large supplies of slack coals available at the col-

lieries in the Midlands and in the North which could in future be delivered within a radius of 50 miles at a cost of about 5*s.* 4*d.* per ton, including carriage; beyond that distance it is probably only rarely economical to pay carriage on very cheap fuel. Three classes of cheap fuels are discussed; (1) the anthracitic coals and refuse coke dealt with in the previous paper; (2) the free-burning small coals of the Midlands; (3) the small caking coals of the North. The difficulty in the direct burning of the latter two classes is in breaking up the clinker so as to allow a proper supply of air at points in the furnace. Descriptions and diagrams are given of the Babcock and Wilcox revolving grate. In order to obtain increased area of grate and to promote smokeless combustion it is recommended that the revolving grate should project in front from under the boiler into an arched fire-brick combustion chamber. At Chelmsford the ratio of cost of fuel per B.T.U. to total cost is 64 per cent. when using coal at 17*s.* 5*d.* per ton; if coal at 5*s.* 4*d.* were available, it is calculated that the ratio would be only 35 per cent. A Table is given of a complete test of a Babcock boiler with revolving grate. In the discussion J. Perry pointed out that for stations with a high load factor it is better to use a cheap fuel, while for a low load factor a more expensive coal would be better; for a load factor of about 15 per cent. they would probably be equally economical. W. Geipel referred to the advantages of a rib beneath the furnaces of a Lancashire boiler in promoting circulation and hence getting up steam more quickly. F. J. Appleby considered the powdered fuel method to be the best way of burning the small bituminous coals of the North.

H. R. C.

Working Expenses of Electrical and Cable Railways.

(Tramway Railway World, vol. ix., April, 1900, pp. 138–139.)

A comparison of the financial results of the Liverpool Overhead and City and South London Electric Railways, and the Glasgow District Subway worked by cable traction.

Table I gives particulars of the three railways relating to the last half-year, and Table II, see p. 483 (which is abstracted from the particulars in the article), gives the financial results for the last six half-years.

TABLE I.

——	Liverpool Overhead.	City and South London.	Glasgow Subway.
Receipts per passenger carried	1·96*d.*	1·92*d.*	1·26*d.*
Train-miles run per double-track mile	59,666	80,598	82,809
Passengers carried per double-track mile	772,956	1,147,647	1,059,310

TABLE II.

Name of Line.	Half-Year.	Per Train-Mile—Pence.							Totals.					Remarks.
		Maintenance of Way, Works, and Stations.	Locomotive Power.	Car Repairs and Renewals.	Traffic Expenses.	General Charges, Taxes, &c.	Total Expenses.	Receipts per Train-Mile.	Per Cent. of Expenses to Receipts.	Total Expenses.	Total Receipts.	Miles Run.	Passengers Carried.	
Liverpool Overhead Electric Railway.	June, 1897	1·80	3·42	0·29	5·41	3·26	14·18	23·79	59·60	21,459	36,026	363,399	4,269,260	Time during which workmen's tickets available has been extended.
	Dec., 1897	2·16	3·71	0·38	5·12	3·44	14·81	24·25	61·07	22,940	37,559	371,773	4,467,490	
	June, 1898	1·89	3·93	0·46	5·59	2·74	14·61	24·63	59·32	22,076	37,220	362,690	4,472,941	
	Dec., 1898	2·14	3·91	0·53	5·57	2·77	14·92	26·12	57·12	23,218	40,656	373,560	4,894,921	
	June, 1899	1·80	4·31	0·46	5·79	2·74	15·10	23·32	64·75	23,624	36,492	375,500	4,475,279	
	Dec., 1899	1·29	4·17	0·27	5·40	2·58	13·71	25·42	53·93	25,007	42,662	402,752	5,214,957	
City and South London Electric Railway	June, 1897	0·59	6·11	0·57	6·25	2·70	16·22	29·15	55·64	15,734	28,260	232,703	3,437,810	Very keen competion with L.C.C. tramways. Cost of fuel no material effect.
	Dec., 1897	0·62	5·83	0·48	6·08	2·65	15·66	27·63	56·68	15,035	26,528	230,396	3,337,861	
	June, 1898	0·76	5·85	0·56	6·03	2·72	15·92	28·10	56·65	15,614	27,552	235,342	3,478,977	
	Dec., 1898	0·83	5·65	0·56	6·17	2·67	15·88	28·28	56·15	15,498	27,588	234,166	3,462,814	
	June, 1899	0·79	5·85	0·48	6·14	2·91	16·17	28·69	56·36	15,851	28,125	235,254	3,540,098	
	Dec., 1899	0·67	5·85	0·48	6·09	2·75	15·84	26·87	58·95	15,968	27,506	241,973	3,442,942	
Glasgow District Subway Cable Traction.	July, 1897	0·88	2·14	0·35	1·63	0·74	5·74	12·01	47·79	12,205	25,541	510,161	4,178,215	Fares very low. Route circular. Expenses per train-mile much increased by higher wages and dearer coal.
	Jan., 1898	0·70	2·99	0·39	1·85	1·22	7·15	12·98	55·08	16,492	29,937	553,307	5,450,177	
	July, 1898	0·76	3·00	0·40	2·08	0·94	7·18	14·44	49·72	16,247	32,682	543,114	5,779,119	
	Jan., 1899	0·83	3·02	0·41	2·08	0·79	7·13	15·54	45·88	16,474	35,925	554,770	6,666,082	
	July, 1899	0·82	3·16	0·24	2·47	0·99	7·68	15·78	48·67	17,520	35,977	547,083	6,505,221	
	Jan., 1900	0·75	3·08	0·23	2·57	1·30	7·93	16·20	48·95	18,471	37,744	558,961	7,150,342	

The Glasgow expenses are only about a halfpenny per passenger, while those of London and Liverpool are about a penny. Glasgow runs the largest number of train-miles per mile of track, but its train is the smallest.

E. K. S.

Metropolitan Electric Supply Company's Works, Willesden.

(Electrician, March 9 and 16, 1900, vol. xliv., pp. 691–697, and 733–738.)

The load on this supply company's stations in London has grown to such an extent that it has been found necessary to increase the generating plant, and also to provide for further large extensions in the future. For this purpose large works have been erected at Willesden, where a very suitable site was procured, about 9 acres in extent, adjacent to the London and North Western main railway line, a branch line of the Midland Railway and the Grand Junction Canal. There are consequently ample facilities for the supply of coal, either by rail or by water. The coal can be conveyed either from the canal or the railway siding by means of a conveyor, constructed by the Temperley Transporter Company, which carries coal directly into bunkers on the roof of the boiler-house. The bunkers can store about 1,000 tons of coal. The coal is lifted in skips, each containing 15 cwt., to the transporter-beam, a height of 55 feet. It is then carried by the traveller into the bunkers, the maximum travel being 274 feet. The full skip *en route* to the boiler-house is stopped and lowered to the platform of a weighing-machine; after being weighed it is again taken up and carried to the bunkers, where each skip is automatically tipped. Electrical power is used for the conveyor.

The boiler-house contains sixteen Babcock-Wilcox boilers, working at 160 lbs., and fitted with Babcock-Wilcox steam superheaters. Six of the boilers are hand-fired, eight are fitted with Vicars automatic stokers, and the other two with Babcock-Wilcox chain-grate stokers. The water used is taken from the canal.

The engine-room plant consists of three large Westinghouse sets; the generators are 2-phase, yield 1,500 kilowatts each, the pressure of each phase being 500 volts, and the frequency 60 per second, with a specified efficiency at full load of 95 per cent. The armatures were tested at 5,000 volts. The exciters are six-pole machines, and yield 450 amperes at 100 volts. Each alternator and its exciter is directly coupled to a Westinghouse vertical compound enclosed marine type engine running at 116 revolutions per minute. There is a surface condenser placed behind each engine. These have been supplied by the Wheeler Condenser and Engineering Company, are of their Admiralty

pattern, and each has a cooling surface of 4,000 square feet. In connection with each is a Blake-Knowles combined air and circulating pump, the two pumps being connected to the same rocking lever. Between the engine and pump is an automatic valve operating a by-pass to an open-air exhaust if the vacuum in the condenser fails. The circulating water is cooled by three Barnard cooling towers, capable of cooling 8,000 gallons of water per hour from 130° F. to 80° F. Their dimensions are 12 feet 3 inches × 12 feet × 37 feet each. The fans are driven by small Bumsted-Chandler engines. A switchboard in the engine-room forms the connecting link between the generators and the high-pressure switch-room.

The overhead travelling crane is by Higginbottom and Mannock; it has a span of 50 feet, and is rated at 35 tons, having been tested up to 50 tons. It is driven by one electric motor for all three motions.

The step-up transformers are installed in a separate room, together with the high-pressure switching gear. The transformers, fourteen in number, of 250 kilowatts capacity each, were made by the British Electric Transformer Manufacturing Company, and are of the Berry type. The transformers for each of the two phases are independent of one another; they are not in cases, and, being thoroughly ventilated, very cool running is attained. The primary coils take 497 amperes at 523 volts, and the secondary coils yield 23 amperes at 11,000 volts. One pole of the high-pressure windings is earthed; no earth shields or earthing devices are used. The high-pressure switching gear has been designed throughout by G. W. Partridge; a fully illustrated description of it is given. On the switchboard the two phases are separated, one being brought to each side. All the outer conductors of the concentric mains are coupled together and earthed. Two fuses in parallel are used in each case, one only being used for light loads; the second fuse is put in circuit as the load gets heavier. The fuses are of tinned copper wires in stoneware tubes 4 feet 6 inches long. The mains are not switched directly on to the transformers; the circuit is first closed through the primary of a charging transformer placed in series with the main transformers, the secondary of the charging transformer being on open circuit; the resistance of this secondary is gradually cut down by means of a water rheostat, the main fuse being eventually put in, and the charging transformer cut out. In switching off the mains the reverse operation takes place.

There are two trunk mains, one for each phase, consisting each of paper-insulated concentric cables, and also an extra one laid alongside as a spare main. The mains are laid under the canal towpath in a cast-iron channel of five ways, with a loose cast-iron lid; full descriptions are given of the disconnection boxes and of the jointing and laying of the cables. At the substations the pressure is reduced to 1,000 volts. The switch gear is similar to that employed at Willesden; all pressure regulation is done in

the substations. There are also a small test transformer and suitable plug switches on the board, for the purpose of ascertaining on which side of the system the extra main has been placed at Willesden in the event of the spare main being required.

The article is fully illustrated, and a complete account is given of the scheme. E. D. P.

Polyphase Distributing System of the Metropolitan Street Railway Company of New York City.

J. E. Woodbridge.

(Electrical World and Engineer, vol. xxxv., March 31, 1900, pp. 463–464; April 7, pp. 501–504; April 14, pp. 541–544; April 21, pp. 579–581; April 28, pp. 613–615; May 12, pp. 698–701.)

The lines owned, leased, or operated by the Metropolitan Company aggregate about 217 miles of track, of which 82 miles is at present worked electrically. Quite recently the Whitney syndicate which controls the Metropolitan Company has obtained a controlling interest in the Third Avenue Railway Company (58 miles of track), and the Union Railway Company (55 miles of track), so that altogether the lines which will be operated from the station now approaching completion will in about a year have 3,000 cars in their sheds, or about 1,500 in actual operation at one time.

The generating plant will, when completed, consist of eleven main engines, each rated at 4,500 HP. with cut-off at maximum economy, but capable of working up to 7,000 to 7,500 HP. apiece.

The following are the leading particulars of the eleven 3-phase generators:—

Type.—Revolving field with external stationary armature mounted between the two halves of the vertical engine.

Output.—3,500 kilowatts normal, or 5,000 kilowatts for 4 hours; voltage, 6,600; frequency, 25; speed, 75.

Shaft.—Compressed steel 37 inches diameter, being the crank-shaft of the engine, the spider secured by two keys each 5 inches × 2½ inches section.

Spider of the field ring has eight arms cast in one piece with the hubs, the fly-wheel hub being bolted up direct to the arms by sixteen 2½-inch bolts at a distance of 4 feet from shaft centre.

Field Ring of cast steel in four sections, each half the full axial width of the ring, and each spanning half the circumference. The rim tension of these rings is carried across the butt joints by means of double-headed keys similar to those commonly used in fly-wheels.

Poles.—Forty in number made of laminated steel with an edge-wise winding. Overall diameter 16 feet 8 inches, giving a peripheral speed of 3,900 feet per minute.

Excitation.—The exciting current at 100 volts to 125 volts is introduced to the revolving field coils by carbon brushes bearing on cast-iron rings. The resistance of the field is $\frac{1}{3}$ ohm, the necessary exciting current for full voltage from the armature (6,600) with non-inductive load being 300 amperes.

Air-gap.—$\frac{5}{16}$ inch at pole centre to $1\frac{1}{8}$ inch at the tips. It is purposely made narrow, and the magnetism has been carried fairly high on the saturation curve, because by working at a high line-density the magneto-motive force of the armature reaction is unable to cause as great a change of the field strength as it would if this density were down on a steeper portion of the magnetization curve. On this account the throwing off of the full non-inductive load causes a rise in voltage of only 5 per cent. The short air-gap reduces the number of necessary field ampere-turns, to which the armature short-circuit current is directly proportional, thus cutting down the latter to the low figure of rather less than 800 amperes per leg, the rated full-load current being slightly over 300 amperes.

Armature Ring of cast iron, $21\frac{1}{2}$ feet external diameter, mounted on sliding foundation plates so that it can be moved axially to clear the field.

Armature Coil built up of laminated steel with eight ventilation spaces. The core bolts do not pass through the plates.

Armature Winding.—On account of the high potential, 6,000 volts to 6,600 volts, the winding is carried in a few large slots per pole rather than a large number of small ones. There are six slots per pole, two per pole per phase, each $1\frac{1}{4}$ inch × $3\frac{3}{4}$ inches deep, and containing former-wound coils, the ends of all coils of two of the phases being bent back to clear those of the third phase, making what is known as the double-chain winding. The connections are such that all the turns of each phase are in series with each other, the three phases being Y connected.

Efficiencies.—One and a quarter load, 97 per cent.; full load, 96·7 per cent.; three-quarter load, 96·2 per cent.; half load, 94·8 per cent.; quarter load, 90·8 per cent.

Weight.—The complete machine weighs 130 tons, the rotating part accounting for about half of this.

The designers appreciated the risks that would accrue were 6,600 volts allowed to concentrate itself on a single fault. On account of this and the widespread character of the public service which would be interrupted by a shut down, all routes over which the power is carried from part to part of the station, as well as from it to the substation, is divided as much as possible. For instance, the conduits which carry the cables from the generators to the switchboard gallery are several in number, and widely separated from each other, the same being true of the vertical cable ducts. Again, although for convenience of operation there is one switchboard, yet much trouble has been taken to distribute the switching apparatus itself over a much greater area than would, for purely mechanical reasons, be necessary. Thus each

switch and each pole of each switch or circuit-breaker is placed within its own cell, separated by brick walls from the other cells, and by double brick walls and intervening air-spaces from other switches or circuit-breakers.

The circuit-breaker is of the oil type, and is operated by compressed air forcing a piston up or down in a vertical cylinder above the top of the brick structure, enclosing the live parts. The valve controlling this cylinder is operated by one magnet. When the magnet is excited and draws its armature down, it pulls a valve—which is a miniature of the plain unbalanced D valves of simple engines—into such a position as to admit air above the piston and exhaust it below, thus forcing the piston down and closing the main current contacts. If current is cut off from the magnet by any means, the valve is instantly restored by a spring into such a position as to admit air below the piston and so open the contacts. The magnet is wound with two coils, one of fine and one of coarse wire connected in series with each other. The movement of the armature works an automatic switch which short-circuits the high resistance part of the winding when the armature is up, thus allowing a powerful current to pass from the constant potential source of supply to draw the armature down with plenty of reserve force. As soon as the armature is down the increased resistance thrown on by the automatic switch reduces the flow of current through the magnet winding to an amount only sufficient to hold the armature in the down position, thus economising current which must be left on as long as the oil circuit-breaker is closed. The exciting current is at 110 volts, and the compressed air for the pneumatic cylinders is supplied by motor-driven air-pumps with automatic controllers.

Comparisons are made between the new type of circuit-breaker and the old type in which three magnets were used. A description is given of the automatic controlling switch with differential magnet for reverse current protection; and also a detailed account of the method of arranging the 'bus bars and various circuits on the switchboard. Numerous illustrations and diagrams are given.

The last and sixth article deals with the high-tension feeders and the substations. The feeders are triple-conductor cables, each conductor having a cross-section equivalent to 4/0. Each cable end is flared out to bell-mouth form to prevent static discharges from piercing the insulation at this point, and static dischargers (which are the same as lightning arresters) are also connected to each end. At the generating station the circuit-breaker, through which the current passes to the feeder, is fitted with an automatic overload relay, and again at the substation the circuit-breaker is fitted with an automatic releasing device actuated by a reverse-current relay. In case a short occurs on any feeder, there will be a rush of current into it from the generators which will operate the overload relay, and at the same time the rush of power back into the other end of the feeder from the substation 'bus bars

operates the reverse-current relay. In this way the feeders are at once cut out of circuit at both ends.

There are six substations, each with from three to six 1,000-kilowatt rotary converters. The step-down transformers—three to each converter—are of the air-blast type, and reduce the voltage from 6,000 to 350.

E. K. S.

Detroit, Rochester, Romeo, and Lake Orion Electrical Railway.

(Street Railway Journal, vol. xvi., April, 1900, pp. 286–288.)

Commencing at Detroit, this railway runs for a short distance over the lines of another company; then over its own track to Rochester, 15 miles; here it divides, one branch going to Romeo 12 miles; the other branch to Lake Orion and Oxford, 13 mile The power station is at Rochester. The boiler house, 47 feet × 70 feet, contains at present two 250-HP. boilers. There are two Deane feed-pumps, each capable of supplying a 500-HP. boiler with water; injectors of the Metropolitan type are also installed, and are connected to both the creek and the city water-mains. The feed-water is brought from a creek, 300 feet away, through a 6-inch cast-iron pipe, in which is a Worthington strainer. The injection water for the condensers also comes from this creek in a 10-inch cast-iron pipe, and is discharged back into the creek through a 15-inch terra-cotta pipe. The engine-room, 50 feet × 70 feet, contains two 325-HP. tandem compound condensing Ball and Wood engines, running at 200 revolutions per minute. Goubert heaters are placed between the low-pressure cylinders and the Deane jet condensers; the feed-piping is so arranged that one or both heaters may be used, or a supplementary heater (fed by exhaust from feed and vacuum pipes); water-relief valves are placed on each heater and feed-pump. Crocker-Wheeler generators are used, 200 kilowatts, 550–650 volts, and direct coupled. A booster set is also installed, consisting of a 150-ampere, 600-volt motor, mounted on the same base with a generator having a capacity of 400 amperes at 150 volts. This generator is in series with the line, and can raise the pressure of the booster feeder from 650 volts to 800 volts.

The track is laid with 56-lb. 60-feet rails on cedar ties, with oak ties at curves and special work. The joints are fastened with six-hole fishplates and protected rail bonds are used. The whole track is ballasted with gravel, of which there is a depth of 6 inches below the ties. Turnouts are 4 miles apart, with telephones at each. Double trolley wire, 00 figure 8, is used, feeders being tapped into it at every half-mile. The poles are of cedar.

The rolling stock consists of eight Kuhlman cars, 45 feet over all, weighing 21 tons, and seating capacity of fifty-four. Two 65-HP. Westinghouse motors are on each car; the brakes used are

of the Magann stored air type. Kalamazoo trolley wheels are used, and are found to run from eighty to ninety days.

The company also furnishes the city lighting for Rochester. The equipment for this consists of a 150-HP. 550-volt motor, direct coupled to a 90-kilowatt Westinghouse alternator, which operates at 11,000 volts. A Chapman voltage regulator is used, and by this means the town lighting pressure is regulated to within a 2 per cent. variation.

E. D. P.

Three-phase Transmission on the Union Railroad, Providence, R.I.

B. Harding.

(Street Railway Journal, vol. xvi., April, 1900, pp. 294–296.)

The Union Railroad Company of Providence is extending its lines into the surrounding country districts. The first of these extensions has a length of 18 miles. The towns along the route are summer pleasure resorts built on the shore of Narragansett Bay. The power station in Providence has a total capacity of about 5,000 HP. To supply current to the new extension line a substation has been erected at Riverview, 14 miles from Providence. At this substation rotary converters are installed receiving polyphase currents from Providence and supplying the line with direct current. At the central station, Providence, there are two 300-kilowatt Westinghouse rotary converters, which receive direct current at 575 volts and deliver two-phase alternate-current at volts 400 with a frequency of 60 cycles per second, when running at 600 revolutions per minute. These machines are guaranteed to give their normal output, 300 kilowatts, for twenty-four hours without an increase of temperature exceeding 40° C. above surrounding atmosphere, and to carry 25 per cent. overload for 10 hours, or 50 per cent. overload for 2 hours, or 90 per cent. overload for 10 minutes, without injurious heating. These rotary converters are provided with separate shunt-wound exciters coupled to their shafts. The fields of these exciting machines are run considerably under saturation-point, so that any increase in speed of the rotary is followed by a large increase in its excitation. The object of this is to prevent the running away of the rotary, which is likely to occur if the direct-current side were simply run as a shunt to the mains, due to the considerable field-weakening effect caused by the armature reaction of lagging currents.

The two-phase currents of the converter are transformed by four 200-kilowatt Westinghouse self-cooling, oil-insulated transformers to three-phase 10,000-volt currents. This is transmitted by three No. 4 copper wires supported overhead by Locke triple petticoat glass insulators to the Riverview substation. Here it is transformed by four Westinghouse transformers of 150 kilowatts

each to two-phase 400 volts. Additional terminals are provided for alternate-current connections corresponding to direct-current voltages of 550, 565, and 580 volts respectively. The current passes from the transformers to the two rotaries, which have a capacity of 250 kilowatts each. The high-pressure three-phase lines are carried overhead upon the poles of the Narragansett Electric Light Company within the city, and on the trolley poles outside the city limits, the wires being arranged in an equilateral triangle 18 inches apart.

The track outside the city limits is single, with turnouts at the stations; it is standard gauge and in good condition, having previously been used as a steam railroad. This track was formerly owned by the New York, New Haven, and Hartford Railroad Company, and was operated by steam. The fare charged from the Union station to Buttonwoods was 25 cents by the steam company; by the electrical company the fare is 15 cents.

Some illustrations are given of the rotary converters and also some particulars of the rolling stock and the times of service.

E. D. P.

Power Transmission at Duluth, Minnesota. F. W. SPRINGER.

(Electrical World and Engineer, vol. xxxv., April 14, 1900, pp. 545–547.)

The St. Louis River drains an area of 38,000 square miles, composed of pine land, swamps, lakes, and some arable land. The rainfall is about 30 inches per annum, and there are two periods of low water, one from summer drought, and the other from the freezing-up of the small streams and swamps, many of which freeze solid. The minimum flow occurs in winter, when the power may be estimated at 15,000 HP. at a head of 600 feet. Recently a St. Louis power development company has been formed, and it is proposed to cut a canal 4 miles in length and to lay 800 feet of pipe line to a power station in the bed of the stream. This will give 350 feet head, or about 10,000 HP. at minimum flow.

The Black River scheme is similar to the above. A masonry dam 20 feet high is to be built, which will give a head of 55 feet and a flow of water of 6,000,000 cubic feet. The pipe line is to be 54 inches diameter, and will be buried to prevent freezing. Two direct-connected polyphase 800-kilowatt generators are to be installed, together with five (one reserve) oil transformers for raising the pressure from 440 to 18,000 volts. The pole line will consist of 35-feet cedar poles, 8 inches diameter at the top and set 52 to the mile, with three pin cross-arms and 24-inch spacing. The conductors will be No. 1 bare copper mounted on three part Locke insulators.

The interesting point about these schemes is that, although

many propositions have been made and much money spent, the development of the power running to waste did not become practicable until the application of long-distance transmission by electricity. With the prospect of the immediate development of such powers it looks as though what had long been hoped for would come to pass—that is, the beginning of the manufacture of iron and steel at Duluth and Superior. It is estimated that it will not cost more than $55 per HP. to distribute the power.

E. K. S.

Dayton (Ohio) Electrical Railways.

(Street Railway Journal, vol. xvi., April, 1900, pp. 277–285.)

The street railways of Dayton are operated by three separate and distinct companies. Each company has its own car-houses, and its own shops, and all have been remarkably successful. Previous to this year there had already been built two railways of 25 miles and 84 miles in length respectively. The three new lines which started operating in January of this year are the Dayton, Springfield, and Urbana, 43 miles; the Dayton and Xenia, 33 miles; and the Dayton-Xenia Rapid Transit, 18 miles long.

Dayton, Springfield, and Urbana Electric Railway.—The line is double track in both Dayton and Springfield, but is otherwise a single line, with turnouts, and is constructed entirely on a private right of way, varying in width from 50 feet to 300 feet.

One generating station is at Medway, the centre of the Dayton-Springfield section; the other, in course of erection, is at Bowlersville, on the Urbana section, and both are of quite similar construction and equipment. The boiler-room, 55 feet × 43 feet 4 inches, contains three 250-HP. Babcock-Wilcox boilers, Blake pumps, Goubert heaters, Stratton separators, and Chapman valves. The station is located on Mad River, and has an abundant water-supply. The equipment of the engine-room, 99 feet × 50 feet 8 inches, consists of three Slater cross-compound condensing Corliss type engines, 450 HP. each, 100 revolutions per minute, direct coupled to three 325-kilowatt Westinghouse generators. One 100-kilowatt Westinghouse booster is used.

The overhead city construction is side pole, with steel poles 28 feet long, in two sections: the lower section, 6-inch pipe, 20 feet long; the upper section, 5-inch pipe, 8 feet long with the joint 18 inches long, swedged and turned on top to shed water. Spans are attached by pole-bonds, with Creaghead strain insulators at the pole, and glass brake knobs are placed in the spans 4 feet on each side of the trolley wire. The rest of the road is equipped with Creaghead flexible brackets, 10 feet long, supported on wooden poles 7 inches diameter at the top, and of lengths sufficient to bring the top cross-arm 24 feet above the track. The poles have two four-pin cross arms, the upper one for the telephone and block

signal system, and the lower one for feeders. In Dayton 95-lb. girder rail is used; in Springfield and Urbana 95-lb. girder section. All rails are in 60-feet lengths, laid on 6-inch × 8-inch × 8-foot ties. The interurban sections are laid with 75-lb. rails. The joints are made with six-hole fishplates, which conceal two ·0000 Crown rail-bonds. The rails are also cross-bonded, and wherever a stream is crossed a heavy copper ground-plate is used. After the subgrade was completed and ditched, a layer of 12 inches of gravel was put on; the ties were covered with the same material, thoroughly tamped. Plate girder bridges resting on stone abutments are used for crossing small streams. There are also three Pratt truss bridges on the line of 156 feet, 136 feet, and 80 feet spans. There are fourteen passenger cars, four combination passenger and baggage cars, one snow plough, and a special Pullman car for parties. Each car is equipped with four B 47 G.E. motors. Ten have G.E.C. electric brakes, and the rest are fitted with Christensen air brakes.

Dayton and Xenia Traction Company's Line.—The generating station is situated near the centre of the Xenia section, on the Little Miami River, which provides an abundant water-supply. The boiler-house contains four 250-HP. Cahall vertical boilers, Cochrane heaters, Buckeye separators, chain grates, Stilwell-Bierce and Smith-Vale pumps and condensers, and Metropolitan injectors. The engine-room contains two 750-HP. cross-compound Buckeye engines, direct coupled to 500-kilowatt Westinghouse generators.

The track is constructed of T-rail, 90-lb. on the Xenia section and 80-lb. on the Spring Valley section. In Dayton 95-lb. grooved rails and in Xenia 90-lb. girder rails are used. All rails are laid on oak ties, 6 inches × 8 inches × 8 feet, spaced 2 feet apart centre to centre, and bedded in gravel. Where the line crosses small streams oak trestles have been erected; there are also several steel bridges on the line. Side pole span construction is used in the cities and villages. The steel poles are in three sections 28 feet long, set in concrete; on the interurban lines 30-feet poles with 7-inch tops are used.

The rolling stock consists of six passenger cars, two passenger and baggage cars, six open single-truck cars, one freight car, one single truck repair car, and one snow plough. The passenger cars are equipped with Christensen brakes, and each car carries four Westinghouse 56-A motors. The road is operated by a telephone system, in connection with a block signal system.

Dayton and Xenia Rapid Transit Railway.—The power-house is situated on the Little Miami River, which provides an abundant water-supply. The boiler-room contains four 200-HP. horizontal water-tube boilers. The engine-room contains two 500-HP. Lane and Bodley Corliss engines driving by belt two 400-kilowatts G.E. generators. Iron pole span construction is employed in Dayton; the rest of the line has wooden poles, to which are attached Creaghead flexible brackets. The track is of 70-lb. T-rails, joined by six-hole angle-bars 30 inches long. The joints are

bonded each with one No. 0000 Atkinson rail bond. The rails are laid on oak ties 6 inches × 8 inches × 8 feet, spaced 2 feet centres and bedded in gravel.

The article is fully illustrated, and also deals with proposed further extensions of the electric railways at Dayton.

E. D. P.

Fremont Three-phase Railway, Ohio.

(Street Railway Journal, vol. xvi., March, 1900, pp. 227–231.)

This is a description of the long-distance, electric, high-speed railway between Toledo and Norwalk. The entire length of the line—60 miles—will be supplied with current from a central power station at Fremont, from which current will be transmitted at high pressure, 30 miles in each direction, to six substations, where it will be transformed down and converted to direct current for feeding the trolley lines. The boiler-house contains five Babcock-Wilcox boilers, each of 300 HP. nominal rating and working at a pressure of 155 lbs. per square inch. The feed-water is pumped from the Sandusky River through one 6-inch and two 14-inch pipes. Two Worthington pumps lift the water from the intake well to two elevated jet condensers which are set over a single hot well. The feed-water is taken from this hot well by a Worthington tank-pump to the treating plant. When neither of the condensers are running, the feed-water is drawn direct from the river through the 6-inch suction-pipe by the Worthington tank-pump; or should this pump be disabled, the feed-pump can draw the water from the river well direct through the 6-inch pipe. The water is treated in two large tanks provided with stirrers worked by electrical power. It is afterwards run into a large filter tank, constructed of Portland cement masonry, which is fitted with a sand filter bed, aluminium-bronze strainers, washing pipes and stirring devices. After leaving the feed-pumps the water passes through an auxiliary heater, where it receives the surplus heat of the auxiliary pumps and engines, thence through an economiser to the boilers. The feed-piping is so arranged that either the heater or economiser may be by-passed. There is coal storage above of 500 tons capacity, from which the coal is fed by gravity to the mechanical stokers. The ashes and refuse are also conveyed mechanically to a bin. A branch line of the Wheeling and Lake Erie Railway passes under the refuse bin, and also over the coal-handling plant, which consists of an endless chain of wheel and pan construction. The coal- and ash-handling machinery is operated by a 10-HP. Westinghouse standard engine. Draught is furnished by two vertical discharge fans, directly connected to horizontal engines, which are fitted with a regulator whereby the speed is increased as the steam pressure falls, and *vice versa*.

A compressed-air system has been installed for cleaning the

electrical machinery. It consists of a Westinghouse Air Brake Company's standard air-pump, storage tank, &c. Four 1,000-HP. vertical compound engines are to be installed, having steam cylinders of 21·5 inches, and 37 inches × 22 inches stroke, and running at 214 revolutions per minute. Each of these Westinghouse engines is directly coupled to a 500-kilowatt Westinghouse three-phase generator. Special devices are to be provided to enable the speed of any engine to be varied from the switchboard. Excitation is provided by two 30-kilowatt direct-coupled Westinghouse sets. Each of these sets is capable of supplying the main generators and the works lights.

The transformer room is under the engine-room, and will be equipped with two banks of three transformers, each of 400 kilowatts of the Westinghouse oil-insulated self-cooling type. There will also be two 200-kilowatt Westinghouse rotary converters installed at the generating station, taking current from the main 'bus bars to supply the contiguous sections of the line. The whole system, both the main generators and the substation plant will be arranged for parallel running. The switchboard arrangements are of the usual kind. Time-element circuit-breakers are installed. The pressure of the main transmission three-phase line is 16,000 volts; each wire is protected by a 16,000-volts Wurts lightning arrester. Each of the six substations contains two 200-kilowatt Westinghouse converters and three 150-kilowatt step-down transformers. Loops are brought out of these transformers to effect different ratios of transformation, so that the pressure on the trolley line may be equalised in different substations. The high tension current is carried by three bare copper wires, one upon each end of a cross arm and the other on the top of the pole. Six feet below the cross-bar is the bracket carrying the trolley wires. On the opposite side of the pole, just above the bracket, are carried the direct current feeder cables. The track is single, with turnouts. Cedar ties are used, ballasted with gravel and stone; Carnegie 75-lb. T rails, Forest City Electric Company bonds, and cross-bonds every 500 feet are employed. The passenger cars are equipped with two 75-HP. Westinghouse railway motors, sufficient for a speed of 50 miles an hour on a straight, level track, and are fitted with Westinghouse air brakes. The car-bodies are mounted on the Barney and Smith improved Class F truck, especially designed for heavy work. Spoke wheels, 36 inches diameter, will be used with axles of hammered iron 5·375 inches diameter. The cars have a seating capacity for fifty passengers. The substations along the line will serve as points for the collection and distribution of freight. Mileage books for 1,000 miles will be sold for 12·50 dollars, and the local fares will be about one-half of those charged by the steam railroad.

E. D. P.

Exeter-Amesbury Electrical Railway, U.S.A.

(Street Railway Journal, vol. xvi., March, 1900, pp. 232–234.)

An illustrated description of the electric railway laid along the highway between Exeter and Amesbury, a distance of 20 miles. The generating station is at Hampton. The boiler-room contains three Ames' horizontal tubular boilers of 125 HP. each, and one 150-HP. Dillon boiler. Water is drawn from an artesian well 154 feet deep. The feed-water heater is of the Lamphear compound type, in which the auxiliary heater is placed inside the primary heater. The feed-water is passed into the primary heater coils receiving the heat due to the exhaust steam of the engines exhausting into the condenser. This temperature is about 120°–130° F. At the opposite end from which the water enters, it passes into the auxiliary heater, through a lower set of tubes to a settling chamber, then through the upper set of tubes to another chamber, and thence to the boilers. The auxiliary heater receives the exhaust steam of the pumps at the top, whence it passes down round the tubes and out to the atmosphere or the hot well. It is seldom that any steam is seen coming from this outlet, the condensation in the heater being so effective. The temperature of the feed-water from the heater, at a distance of 12½ feet, with everything running, is about 210°–212° F. The pumps and condenser, 800 HP., are all of the Davidson make. The engine-room contains one cross-compound Buckeye engine, cylinders 16·5 inches and 30·5 inches × 30 inches stroke, 350 HP., directly coupled to a G.E. generator of 250 kilowatts, running at 120 revolutions per minute. Also two simple Buckeye engines, cylinder 15·25 inches × 24 inches stroke, 180 HP., running at 160 revolutions per minute, and belt coupled to two Keystone generators of 125 HP. each. In addition, for lighting purposes, there is a tandem compound Buckeye engine, 175 HP., driving by belts an 80-arc-light Brush machine and a G.E. alternator of 1,500 lamps capacity. The car-house, 250 feet × 50 feet, is separate, and can accommodate twenty-four cars. In the rear are six pits with brick sides and cement bottoms, and in the front is a cement floor where the cars are washed. At the rear of the car-house, and separated from it by a fireproof wall is a repair shop and stock-room. The overhead line is mostly of the side pole construction, with Creaghead flexible brackets. The track is of T rails. The rolling stock consists of eight fourteen-bench open cars, ten ten-bench open cars, nine closed cars, and two freight cars, also several Taunton ploughs. Two motors of 35 HP. each are used on the ten-bench cars, and two 50-HP. motors on the closed cars. The car trucks are of the Dupont make. There is a branch line to Hampton Beach, a popular pleasure resort.

E. D. P.

Polyphase Transmission at Montpelier, U.S.A. J. L. Thomas.

(Electrical World and Engineer, vol. xxxv., April 14, 1900, pp. 544–545.)

The plant now opened by the Consolidated Lighting Company, of Montpelier, is composed of a water-power generating station at Bolton Falls on the Winooski River, Waterbury; a steam-plant and two step-down transformer houses in the city; and a step-down transformer-house that is being erected at Barre, 6 miles from Montpelier, and 23 miles from Bolton Falls. The water-power plant consists of two 450-kilowatt General Electric three-phase, 60-cycle, generators, delivering current direct to the line at 11,000 volts. They are direct connected to horizontal turbines operating under a head of 50 feet. The 17 miles of line between Bolton and Montpelier consists of three No. 4 bare copper wires supported on porcelain insulators on a six-pin cross arm. Three more wires are to be added later for power-work. The step-down transformers are 100 kilowatts of the air-blast type, 11,000 to 2,000 volts, and are provided with expulsion cutouts and oil switches.

E. K. S.

Electrical Equipment of the Chicago Great Western Railway Shops.

(American Electrician, vol. xii., April, 1900, pp. 177–178.)

The generating plant consists of three 100-kilowatt Crocker-Wheeler machines, driven by two tandem compound Ideal engines. Engines and generators are coupled by magnetic clutches and run at 250 revolutions per minute. One engine has sufficient capacity to drive two of the generators, the other is half the size; but the smaller engine is provided with an auxiliary steam connection by which high-pressure steam may be admitted to the low-pressure cylinder, thus furnishing means by which the engine may be run on 100 per cent. overload: the mechanical parts of this engine are designed with this in view. Three Stirling boilers are installed under a guarantee to evaporate into steam containing not more than 3 per cent. moisture, from and at 212°, eight pounds of water per lb. of coal burned with a draught of 0·6 inch at the base of the stack, the calorific value of the coal being taken as 11,500 B.T.U. per lb. The exhaust steam is passed through oil extractors and used to heat the building.

Current for both motors and lamps is supplied at 220 volts; there are 600 16-candle-power incandescent lamps and fifty-one 1,200-candle-power arc lamps used. All tools and machinery are driven by electric motors, except some pneumatic tools in the boiler and erecting shops, and the air lifts. The contract requires that all motors shall deliver their rated output for 18 hours per day,

with an average efficiency for all sizes of not less than 88 per cent. at full load, 86 per cent. at three-quarters load, and 83 per cent. at half load; to be capable of carrying 25 per cent. overload for two hours with safety, and in starting to be able to develop 50 per cent. more than their rated output. Thirty motors, varying in size from 2 HP. to 60 HP., are used in the shops. All are Crocker-Wheeler machines except a G.E.-52 motor for the transfer table and the motors on the machine shop crane. The transfer table takes current from two overhead wires, and is capable of carrying the largest coach and the heaviest locomotive used in railway practice. The tools of the machine shop are driven by belts from two lines of shafting each 75 feet long and each driven by a 20-HP. motor. The two shafts can be coupled together by an Arnold magnetic clutch, so that one motor may be used to drive the two. The boiler-shop tools are driven by one 20-HP. motor in a similar manner. The bulk of the power is used in the wood mill, where there are five shafts each driven by a motor. The blacksmiths' shop is equipped with down-draught forges, with Sturtevant fans driven by a 25-HP. motor, also a small steam-hammer, a punch and shear, and a forging machine, driven by a 10-HP. motor. In the yard the turntable, the coal-shoot, and other labour-saving apparatus are also to be equipped for electric power.

The article is illustrated by two views of the generating plant and a vertical cross-section showing the arrangement of the power-house.

E. D. P.

Electrical Equipment of a Packing House. J. E. Smith.

(American Electrician, vol. xii., May 1900, pp. 201–208.)

At the great Armour meat-packing establishment in Chicago sixteen scattered steam-engines were previously used, but these have now been replaced by a compact electrical generating plant supplying power to motors throughout the works. The boilers are of the Wickes vertical water-tube type, and each is rated at 375 HP. They supply steam to three Corliss compound condensing engines, each of which is coupled direct to a 550-volt dynamo, supplying current for motors, and is also coupled by ropes to a 1,100-volt alternator for incandescent lighting. The motors range from $1\frac{1}{2}$ to 200 HP., and number altogether 111, aggregating 3,600 HP. In most cases one motor is used for each floor, single reduction toothed gearing being generally employed between motor and shafting. Compressed-air motors are installed in the cold-storage rooms.

W. H. E.

Electrolytic Etching and Engraving. J. Rieder.

(Elekt. Runds., vol. xvii., April 15, 1900, pp. 139–140; and May 15, 1900, pp. 161–163.)

In this process the article to be etched or engraved is made the anode in an electrolytic bath. In order to produce designs in relief without repeated "stopping off" with an insulating coating of the parts which are not to be etched, the Author produces a liquid surface of the reversed form of the raised design to be obtained. This surface is formed by a plaster-of-Paris mould of the object to be copied, the back of this mould dipping into a solution of ammonium chloride, in which the kathode dips. The steel plate to be etched rests on the top of the moulded surface of the plaster-of-Paris block above the level of the liquid and forms the anode. On passing the current the metal is gradually eaten away until it touches the whole of the moulded surface of the plaster of Paris. In order to enable it to be determined when the etching is complete, and to permit the particles of carbon set free from the dissolved steel to be brushed away, the Author has designed a machine whereby the steel plate can be raised from the plaster of Paris, brushed and replaced exactly in its original position; it is then left in contact for 15 seconds, then raised and brushed, and so on. The current, for a steel plate 200 millimetres × 300 millimetres, increases up to 50 amperes at 12 volts to 15 volts. Further details of the process and the machine are given in the original Paper, which is illustrated.

C. K. F.

Becker's Electrolyser for Alkalies.

(Electricien, vol. xix., May 19, 1900, pp. 316–318.)

This electrolyser is designed for the production of metals from their fused salts or oxides, and is especially applied to the production of sodium and magnesium.

The electrolyser consists of a metallic vessel, provided at its base with a tubular aperture through which the kathode enters the vessel. The joint between the kathode and this tube is made by cooling and solidifying the salt undergoing electrolysis at this point. The kathode is constructed of metal, and should be conical in form, to facilitate the floating upward of the globules of metal which collect upon it. Another form of kathode is described. The anode should be of carbon or of metal, according to the composition of the electrolyte. It is made annular in form, and surrounds the kathode. The connection with the current supply is made by numerous wires attached to its external surface. The apparatus is completed by a flat cone-shaped cover, which is fixed just below the surface of the molten electrolyte over the kathode,

and is designed to receive and protect from atmospheric action the metal separated at the kathode. The upper part of this collector is exposed to the air, and should it still become too heated, it can be cooled by artificial means. It is connected to the negative pole of the dynamo through a resistance. It thus acts as an auxiliary kathode, and any metal collecting underneath it is kept negatively charged until passed from the cell by the side delivery tube.

For the preparation of metallic sodium a mixture of sodium hydrate and sodium carbonate is recommended as electrolyte. The form of electrolyser described above is patented in Europe and in the States. Two cells, the one designed to utilize a current of 500 amperes, and the other a current of 1,000 amperes, are installed at the *Affinerie Electro-metallurgique de Bellegarde sur Valserine.* Three diagrams illustrate the article.

J. B. C. K.

Charging for Electrical Energy. W. W. Lackie.

(Institution of Electrical Engineers Journal, vol. xxix., pp. 678–689; Discussion, May, 1900, pp. 689–690.)

Dividing the total costs of production into standing and generating costs, the Author apportions the former as follows, in the case of the Glasgow Corporation Electricity Department:—

—	Cost per Kilowatt.			Depreciation.			
	£	s.	d.	Rate per Cent.	£	s.	d.
Land and buildings	14	0	0	1	0	2	9
Machinery	25	0	0	7½	1	17	6
Accumulators	2	0	0	10	0	4	0
Mains and cables	44	0	0	2½	1	2	0
Meters	4	0	0	6	0	4	9
Instruments	0	18	0	5	0	0	11
Office furniture	0	2	0	5	0	0	1
Total per kilowatt	£90	0	0	Total	£3	12	0

This amounts to 4 per cent. on the capital for depreciation, while interest at 3·1 per cent. and sinking fund at 1 per cent. make up the total to 8·1 per cent., or £7 5*s.* 9*d.* per kilowatt installed. To this is added £1 10*s.* 3*d.* for rent, rates and taxes, and management, making £8 16*s.* in all for the standing charges.

The generating costs are as follows (1899):—

	d.
Coal	0·54
Oil, &c.	0·06
Wages	0·26
Repairs	0·42
	1·28*d.* per unit.

The maximum demands of all the consumers aggregate 70 per cent. of the supply applied for, while the maximum demand on the station is 50 per cent. of the same. Taking the former value, each consumer must pay £6 4*s.* per kilowatt per annum + generating costs. In Glasgow this may be done by paying 12 monthly instalments of 10*s.* 4*d.* per kilowatt + 2*d.* per unit, or 4*d.* on each of 365 units per kilowatt + 2*d.* per unit, *i.e.*, 6*d.* per unit for 365 hours' use of the maximum demand per annum, and 2*d.* per unit afterwards. Customers who agree to pay for 1825 hours' use of the maximum demand per annum are charged a uniform rate of 2*d.* per unit.

A comparison with the corresponding charges in the Gas Department is given, showing that the maximum demand system is inapplicable to the latter.

The Author next points out certain reductions likely to be made in the future, making a capital cost £65 per kilowatt, and the standing charges £3 17*s.* per kilowatt instead of £6 4*s.* The prices might then be 3¾*d.* and 1¼*d.* per unit, or 1*s.* 8*d.* per annum per 8 candle-power lamp fixed + 1¼*d.* per unit supplied. If a uniform rate per unit is adopted, it must be different for different classes of consumers, according to their probable hours of use. A comparison of the charges in various towns on the maximum demand system is given, with a diagram, and the Paper ends with a number of Tables.

In the discussion H. A. Mavor pointed out that in private installations distribution costs are absent, and labour charges less than in central stations, and E. G. Tidd considered the depreciation rates too high. In reply, W. W. Lackie said that in a central station only half as much plant need be installed as would be required in an isolated installation.

A. H. A.

Dortmund Electricity Works. J. R. Dick.

(Electrician, vol. xlv., May 4 and 11, 1900, pp. 42–45 and 81–95.)

System: Continuous current in urban, and three-phase in suburban, areas, both for lighting and power. The boiler-room contains water-tube boilers, 170 lbs. working pressure, with superheaters. Efficiency 70 per cent. when working at 140 lbs. and 27° F. superheating, burning good steam coal. The engine-room contains four 600-I.HP. horizontal compound condensing engines running at 90 revolutions per minute. The steam consumption is 14·3 lbs. per HP. hour when working at 500 I.HP. Two of the engines drive directly 30-pole continuous-current twin dynamos with distinct armatures and common magnets. Each armature gives 200 kilowatts at 220 to 370 volts. Two armatures can be coupled in parallel for charging batteries or three-wire system, or in series for

traction. The remaining two engines drive directly 400-kilowatt 2,600-volt three-phase generators, having a periodicity 50, excited from the continuous-current 'bus bars. The feeders are of steel armoured lead-covered single cables not exceeding 0·3 square inch area, at a potential difference of 200 volts with no middle wires. There are 13 feeders radiating from the first substation, 16 from the second, and 9 from the third. The average section is 0·15 square inch. The distributors are of steel-armoured lead-covered cables, with earthed middle wire of bare tinned copper, all having an equal section. The three-phase distributors are three-core lead-covered steel-armoured, laid directly in the ground. The voltage is 2,600 volts reduced to 120 volts by single transformers on consumer's premises. The three substations are each equipped with a Gottfried Hagen battery of 132 accumulators, having a capacity of 3,536, 1,768, and 1,768 ampere hours respectively; efficiency 80 per cent. in kilowatt-hours. The price charged is 6*d.* per unit for lighting and 2½*d.* per unit for power, with discounts based partly on units sold and partly on load factor of kilowatts installed. *Drawings:* Scale plan of engine-room, diagrams of switchboard connections, load curves, and maps of mains.

J. T. R.

Obliquely-Crossed Cylindrical Lenses. S. P. THOMPSON.

(Phil. Mag., vol. xlix., March, 1900, pp. 316–324.)

This Paper consists of an attempt to arrive at easier rules for obliquely-crossed cylindrical lenses. Sometimes ophthalmic surgeons prescribe (for the correction of astigmatism) a lens with two cylindrical curvatures on the respective faces of the lens, not crossed at right angles but at some oblique angle. As such lenses are difficult of manufacture, and as their optical effect can be precisely reproduced by a suitably calculated and more readily ground sphero-cylindrical lens, the optician desires to have simple rules for calculating the equivalent sphero-cylinder. The Author discusses this problem, which is that of finding the combination consisting of one thin cylindrical lens and one spherical lens, which will be the optical equivalent of a system made up of two thin cylindrical lenses placed in contact behind one another, with their axes making with each other a certain angle. He finds that two given cylindrical components A and B may be compounded to find their cylindrical resultant C by means of a parallelogram, in which, however, the angle between A and B is drawn as double the actual angle between the axes of the two given components. Hence follows a simple graphic construction for obtaining the required solution of the problem, so far as the cylindrical part of the desired equivalent combination is concerned. The Author next considers the method of obtaining the corresponding expression

for the power D of the spherical part of the equivalent combination, which is found to be—

$$D = \frac{A + B - C}{2}.$$

The results obtained are stated in three working formulæ as follow:—

$$C = A^2 + B^2 + 2\,A\,B \cos 2\,\theta \quad . \quad . \quad . \quad (1)$$

$$\text{Sin}\, 2\,\phi = \frac{B}{C} \sin 2\,\theta \quad . \quad . \quad . \quad . \quad (2)$$

$$D = \frac{A + B - C}{2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Where θ = the angle between the axes, $O\,a$ and $O\,b$, of the two given cylindrical lenses having powers A dioptrics and B dioptrics respectively; ϕ = the angle between the axes $O\,a$ and any line $O\,c$ drawn through O, along which are taken the cylindrical components of the two given cylindrical lenses A and B.

J. J. S.

Modern Explosives. W. MACNAB and E. RISTORI.

(Proceedings of the Royal Society, vol. lxvi., April 14, 1900, pp. 221–232.)

The Authors are carrying out a series of experiments to determine the actual maximum temperature reached during the explosion of various explosive materials in a closed vessel. For measuring the temperature they use the pyrometric method developed by Roberts-Austen, modifications being introduced to overcome the difficulties of the very high temperature, the extreme shortness of duration of the maximum temperature, and the necessity of carrying out the explosion in a closed space. The calorimetric bomb employed is similar to that already described by the Authors, with the addition that in the lid are inserted two insulated conical pins, one of pure platinum and the other of platinum alloyed with 10 per cent. of rhodium. The pins are connected on the outside of the lid with the terminals of the galvanometer, and on the inside with the platinum and platinum-rhodium wires constituting the thermoelectric couple; the portions of the wires in contact are fused together and the junction drawn through a die so as to make it of the same diameter as the rest of the wire. The photographic method of recording the temperature is made use of, the couple being placed in that position of the bomb which is found experimentally to give the greatest and most uniform deflection of the galvanometer. The results of a series of experiments with 10 couples of varying cross-section are given,

and show that for cross-sections greater than about 0·00037 square inch in area, the deflection of the galvanometer is inversely proportional to that area; with thinner couples a greater deflection is obtained than would correspond to a straight line law. The deflection for an infinitely thin couple, which would take up instantly the high temperature obtained in the bomb, can hence be deduced and would correspond to the real maximum temperature. The general uniformity of the results obtained by the Authors is shown by the following Table, which gives the deflections produced with different couples, the charge consisting of 4 grams of Ardeer ballistite, containing 70 per cent. gun-cotton and 30 per cent. nitro-glycerine.

Area of Section of Couple in Square Inches.	Deflection on Scale in Millimetres.	
	Mean of several Readings.	Maximum.
0·00152	83·0	85·0
0·00125	97·0	102·0
0·00099	112·5	115·5
0·00061	132·5	138·5
0·00053	148·0	149·0
0·00037	154·0	158·5
0·00025	165·5	170·0
0·00017	189·0	192·0

It is found that, within reasonable limits, the size of grain of the explosive exercises no influence on the deflection obtained. Experiments with gun-cotton, cordite, and ballistite show that the lowest temperature is that yielded by gun-cotton, and that with ballistite the temperature reached is higher as the proportion of nitro-glycerine increases; cordite, although it contains 58 per cent. of nitro-glycerine, yet, on account of the vaseline present, gives a temperature lower than ballistite containing only 30 per cent. of nitro-glycerine but no vaseline. The results obtained up to the present are purely comparative, and experiments are now in hand for the purpose of determining the value of the galvanometer deflections in degrees of temperature.

T. H. P.

Stereoscopic Rangefinder. C. Pulfrich.

(Phys. Zeitschr., vol. i., pp. 98–102; Discussion, 1899, pp. 102–104. Report read before the Naturforscherversammlung in Munich.)

The rangefinder which this Paper deals with is the one now made by Zeiss of Jena, the original idea and fundamental design emanating from the late H. de Grousilliers.

The instrument consists essentially of a Helmholtz "Tele-

stereoscope," with scales introduced in the two eyepieces. These two scales are so graduated and so arranged that when viewed simultaneously in the eyepieces with the two eyes, the two scales seem to combine and to represent one scale stretching from the observer away to an infinite distance in the landscape. To find the range of any object, it remains only to judge which mark on the scale seems to be at the same distance as the object is from the observer.

The accuracies claimed for the different sizes of instrument are as follows:—

Range.	1 Magn. = 8. Base = 50 Centimetres.	2 Magn. = 14. Base = 87 Centimetres.	3 Magn. = 23. Base = 144 Centimetres.
Metres.	Metres.	Metres.	Metres.
500	9	3	..
1,000	35	12	5
2,000	141	50	18
4,000	564	200	70
8,000	..	800	280

J. B. H.

Thermal Unit. E. Warburg.

(Phys. Zeitschr., vol. i., pp. 171–173; Discussion, January 6, 1900, p. 173. Read before the 71st Naturforscherversammlung in Munich.)

After reference, historical and critical, to the establishment of the Regnault 0°–1° unit, the Author considers that, in view of our knowledge of the change in the specific heat of water from 0° upwards, it is now necessary to redefine the unit of heat. Retaining the erg as theoretical unit, he gives the preference to a water calorie defined for a specific temperature as a secondary unit, and proposes to define the calorie as the quantity of heat that would raise a gramme of water from $14\frac{1}{2}°$ to $15\frac{1}{2}°$.

G. E. A.

Thermo-dynamical Properties of Superheated Steam.

J. H. Grindley.

(Roy. Soc. Proc., March 3, 1900, vol. lxvi., pp. 79–85.)

In experiments on wire-drawing saturated steam the law of adiabatic expansion is assumed to hold during the flow, and is used in obtaining temperature results from wire-drawing calorimeters

for the determination of the initial dryness of steam. If the assumption is correct, it appears, from the theory, that when the ratio of the lower to the higher pressure on opposite sides of the orifice is diminished below a certain value, the higher pressure being constant, the rate of discharge of the steam should be constant. For saturated steam this ratio is 0·5824. If the flow of steam be truly adiabatic this ratio giving maximum flow should be actually found by experiment; if some other value be found, the law of flow is not adiabatic. An experiment was made with an orifice drilled in a piece of thin brass, when it was found that the maximum discharge did not occur until the pressure ratio had fallen to 0·333—a value far below that indicating adiabatic flow. A later experiment was made with an orifice drilled in a glass plate, the experimental results showing a complete agreement with the theory of adiabatic flow.

Experiments were conducted with saturated steam at a known pressure and temperature in the steam chest, but at different degrees of wetness in different experiments. The maximum difference of temperature at any particular pressure in the wire-drawn steam which could be found to exist between experiments with different degrees of wetness was 0·35° F. Generally the difference could not be distinguished; if the dryness of the steam before passing the orifice had been altered by so little as 0·06 per cent., a difference of 1° F. should have been observed in the temperature of the wire-drawn steam. Between the limits of temperature obtained by wire-drawing saturated steam at temperatures varying from 240° to 380° F., the condition of a perfect gas was not obtained, even when the wire-drawing was continued to 3 lbs. or 4 lbs. per square inch absolute pressure. Between the same temperatures, and between pressures of 2·5 and 195 lbs. per square inch, the specific heat at constant pressure was found to increase with temperature, the mean specific heat at atmospheric pressure between the temperatures 230° and 246° being 0·4317, and between the temperatures 295° and 311° the mean specific heat was 0·6482. The variation in the specific heat with the pressure is very small compared with the variation with temperature.

The specific heat K_p and the cooling effect $\frac{\delta\theta}{\delta p}$ or c are considered. The cooling effect c is found to be inversely proportional to $\tau^{3.3}$, where τ is the absolute temperature. It is then shown that the formula $\frac{\delta}{\delta p}(K_p) = -\frac{\delta}{\delta\tau}(c\,K_p)$ is capable of strict proof.

A. S.

Conductivity and Permeability of Iron Alloys.

W. F. BARRETT, W. BROWN, and R. A. HADFIELD.

(Proceedings of the Royal Dublin Society, vol. vii., January, 1900, pp. 67–126.)

The Authors determined the electric conductivities and magnetic permeabilities of over a hundred alloys of iron manufactured at the Hecla Steel Works, Sheffield. The specimens are divided into three classes. The first class consists of alloys containing one constituent besides iron, and comprises carbon, manganese, nickel, tungsten, aluminium, silicon, chromium, and copper "steels." The second class contains two admixtures, the main admixture consisting of nickel, manganese, chromium, or aluminium. The third class contains three or more admixtures. As regards conductivity, the Authors conclude that (1) in all cases a larger, and in some of the alloys a very much larger, increase in electric resistance is produced by the first additions of the added element than for similar amounts added after the alloy is rich in that particular element; (2) the increase in the electric resistance of iron produced by alloying it with an equal percentage of different elements varies through a wide range, according to the nature of the added element, but this increase of resistivity does not appear to be connected with the specific resistance of the added metal; (3) taking the specific electric resistance of mild steel, or of iron containing approximately the same amount of impurities as are present in the alloys tested, to be about 15 microhms per cubic centimetre at the temperature of the air, then the addition of corresponding amounts (say 3 per cent.) of the following metals raises the resistance in the case of annealed alloys of iron and

3 per cent. of	Tungsten	to about	17,	or an increase of	2	microhms.
,,	Nickel	,,	21	,, ,,	6	,,
,,	Chromium	,,	24	,, ,,	9	,,
,,	Manganese	,,	30	,, ,,	15	,,
,,	Silicon	,,	45	,, ,,	30	,,
,,	Aluminium	,,	48	,, ,,	33	,,

Among a large number of valuable results may be mentioned the discovery of a nickel-manganese steel having a specific resistance of 97·52 microhms per cubic centimetre at 15°, probably the highest resistivity of any metallic conductor yet obtained as wire in a commercial form. It is sixty times greater than the resistivity of pure copper, nearly ten times as great as that of the best iron, and 4½ times greater than that of German silver. The alloy contains 25 per cent. of nickel, 5·04 per cent. of manganese, and 0·6 per cent. of carbon.

In the second part of the Paper, dealing with the magnetic properties of the various specimens, the most remarkable result is the effect produced upon iron by the addition of silicon. The

addition of 2 per cent. to 5½ per cent. of silicon to steel increases the magnetic softness to such an extent that the coercive force and retentivity are reduced to nearly one-half of the standard iron rod, which contains only 0·03 per cent. of carbon. The permeability is also higher than that of iron for magnetising forces below saturation.

E. E. F.

Elasticity and Strength of Copper. C. Guidi.

(Accad. Sci. Torino, Atti., 1899–1900, vol. xxxv., pp. 223–230.)

This Paper contains the results of experiments on the elasticity and resistance to tension of bars of copper made from plates employed in the construction of the fire-box of a locomotive. It is known from the experiments of Bach that repeated tests of ever-increasing intensity increase the elasticity of a bar. Owing to variations of pressure within the boiler the plates of a fire-box are subjected to varying strains. The increase in elasticity, however, in the cases studied is not large, and the elasticity is less than half of that which can be obtained artificially by the method of Bach. Tables and curves accompany the Paper.

A. G.

Impact Tests of Material in Tension.

W. K. Hatt and E. Marburg.

(Engineering News, February, 1, 1900, vol. xliii., pp. 74–75. From a preliminary report read before the American section of the International Association for Testing Materials.)

The authors briefly review the early experiments, and the more recent experiments of Kirkaldy and Le Chatelier. They then describe some slow tension-tests and tests in longitudinal shock made at Purdue University during the past two years on iron and steel wires from ⅛ inch to ⅛ inch diameter, ranging in length from 4 feet to 9 feet. The machine used is of a type in which the hammer is hung on the specimen, and impact takes place at the upper head. The hammer varies from 845 to 1,230 lbs., and the range of motion is from 3 inches to 7 feet. The anvil on which impact occurs at the upper head consists of two oak pieces 4 inches square in section bridging the 20 inches clear span between the uprights of the machine, supporting a cast-iron block 14 in. × 18 in. × 6 in., which in turn supports a steel block 4 in. × 4 in. × 14 in. A pencil attached to the hammer describes a curve on the surface of a revolving drum, whose speed is determined by the record of a tuning-fork. The total elongation

of the specimen is thus recorded on the drum, as well as the velocity of the weight before and after impact. A summary of the observations shows that the ultimate extension, contraction of area, and resilience were not different for Norway iron and medium steel wire $\frac{1}{8}$ inch diameter under slow loading and under impact. One specimen broke in two places, and in other cases more than one neck developed in the specimen. In impact on wires of smaller diameter, the elongation in different foot-lengths varied irregularly, while in slow tension-tests on the same material the elongation decreased regularly on each side of the fracture. In thick wires the elongation was as uniformly distributed in slow as in rapid tests.

Detailed results will be published when the investigation is sufficiently advanced.

A. S.

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TO THE

MINUTES OF PROCEEDINGS,

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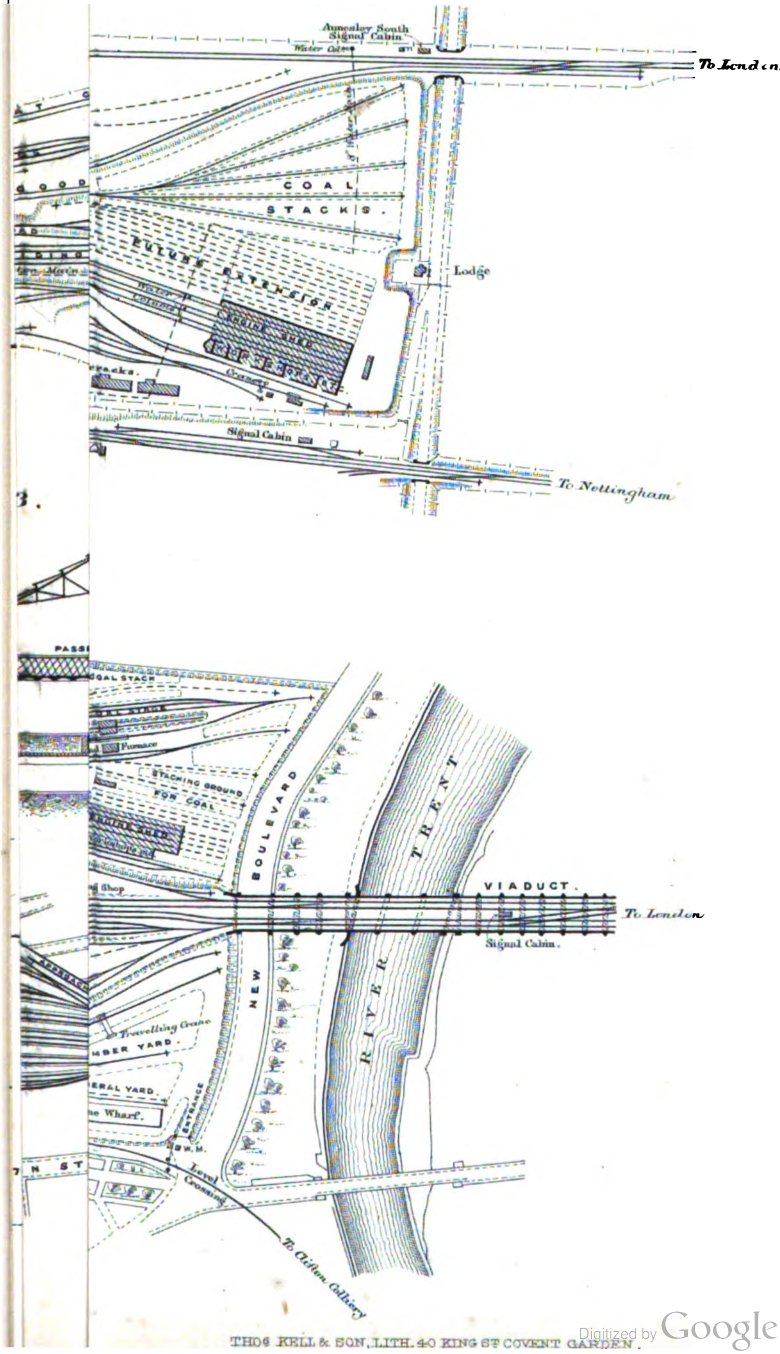
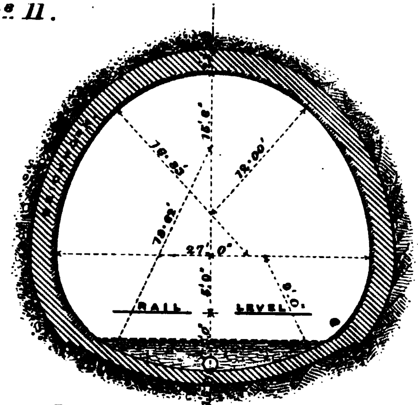


THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.

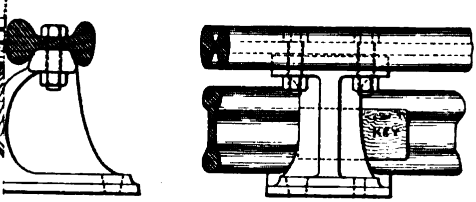
Figª. 11.

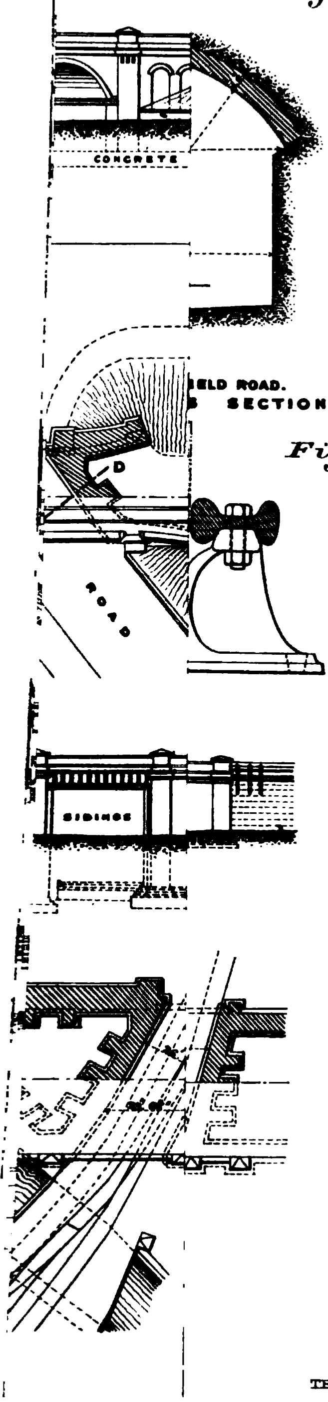


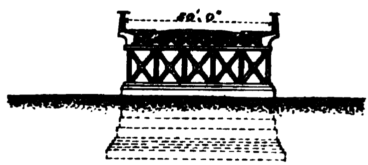
ELD ROAD. EAST LEAKE. DUNTON BASSETT.

SECTIONS OF TUNNELS

Figª. 12.





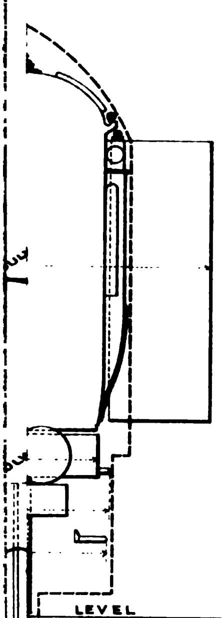


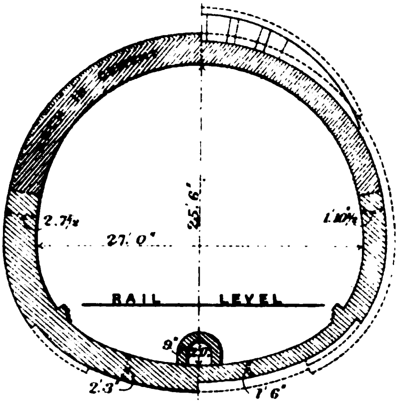
CROSS SECTION A A.

THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.

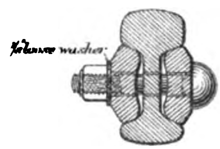
PLATE.3.

Fig: 6.





CROSS SECTIONS OF TUNNEL



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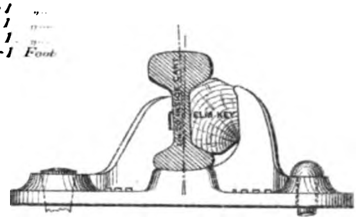

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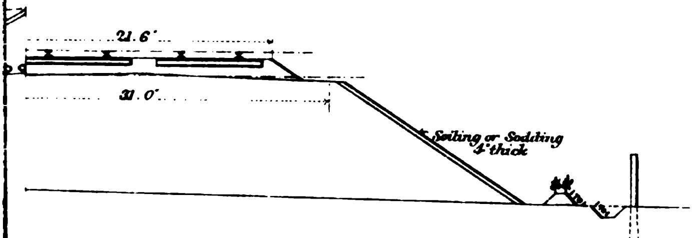
FOR SIDINGS



...LWAY EMBANKMENT

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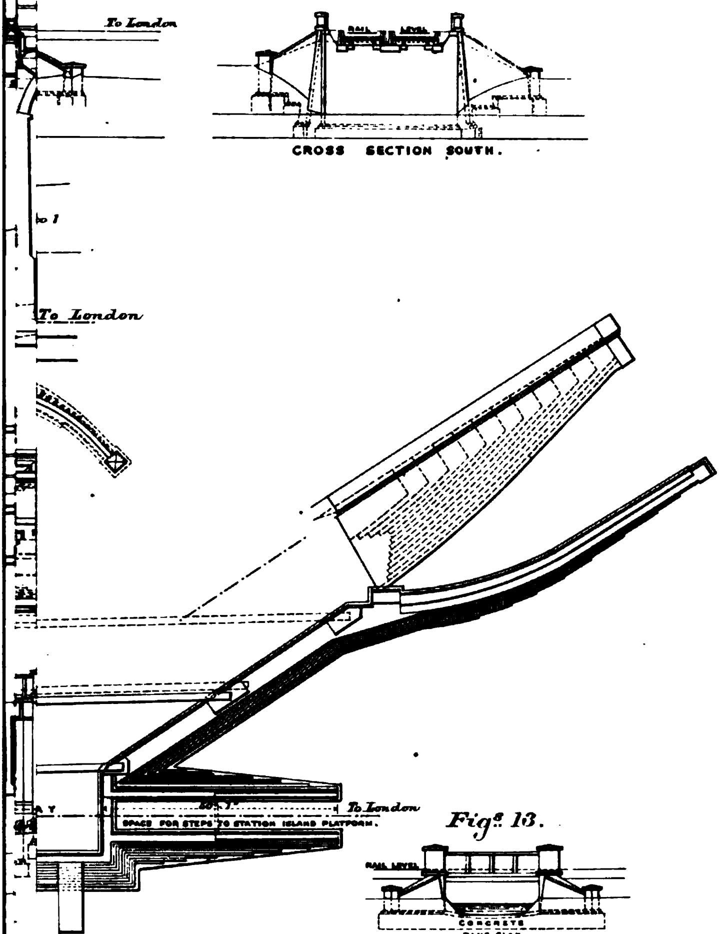
Figs. 12.



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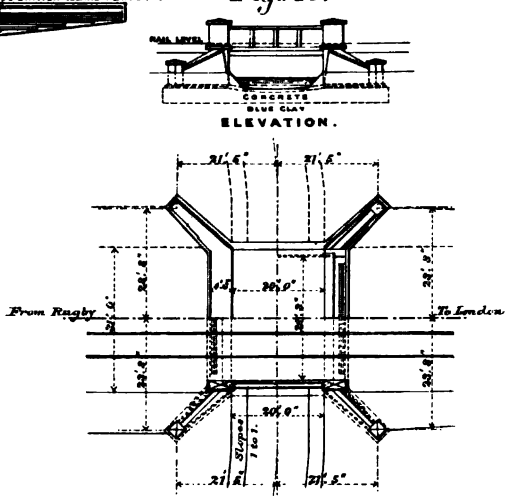

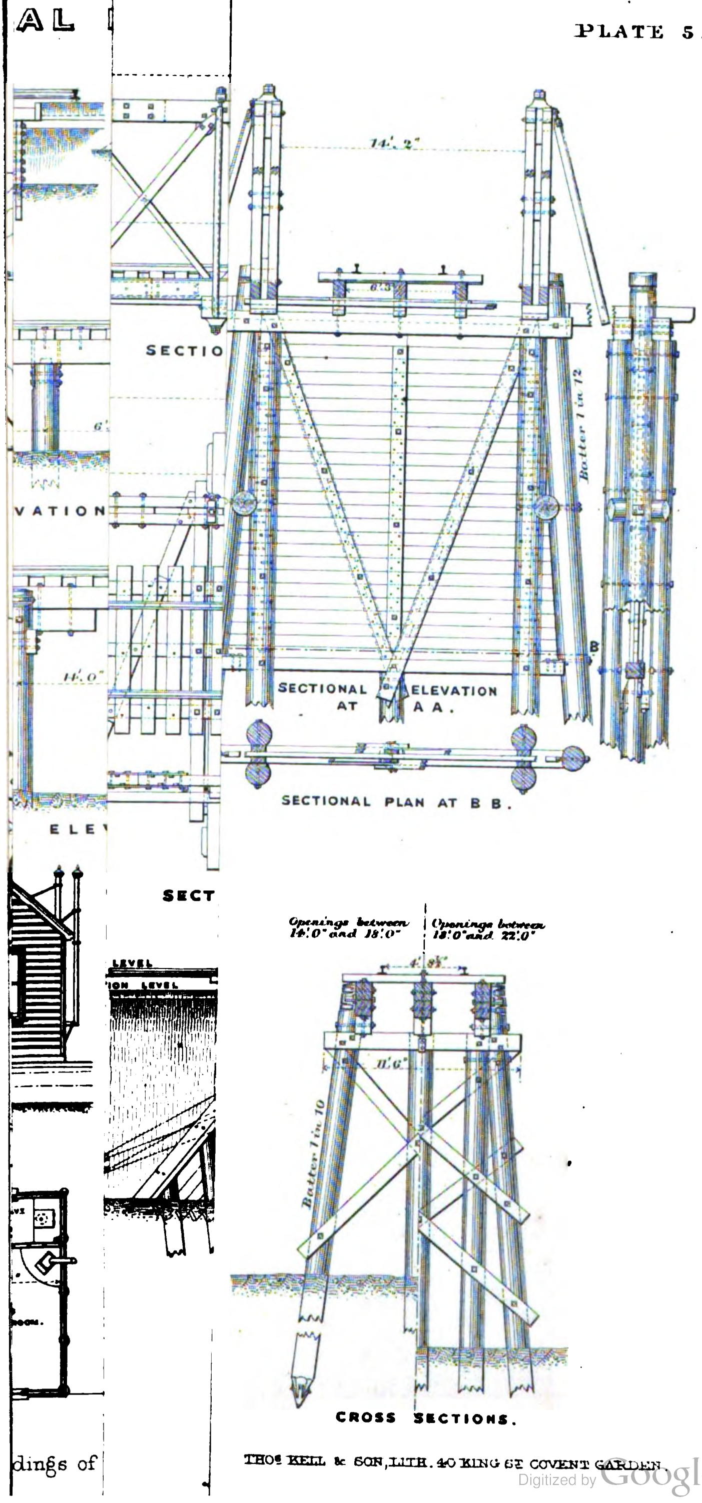

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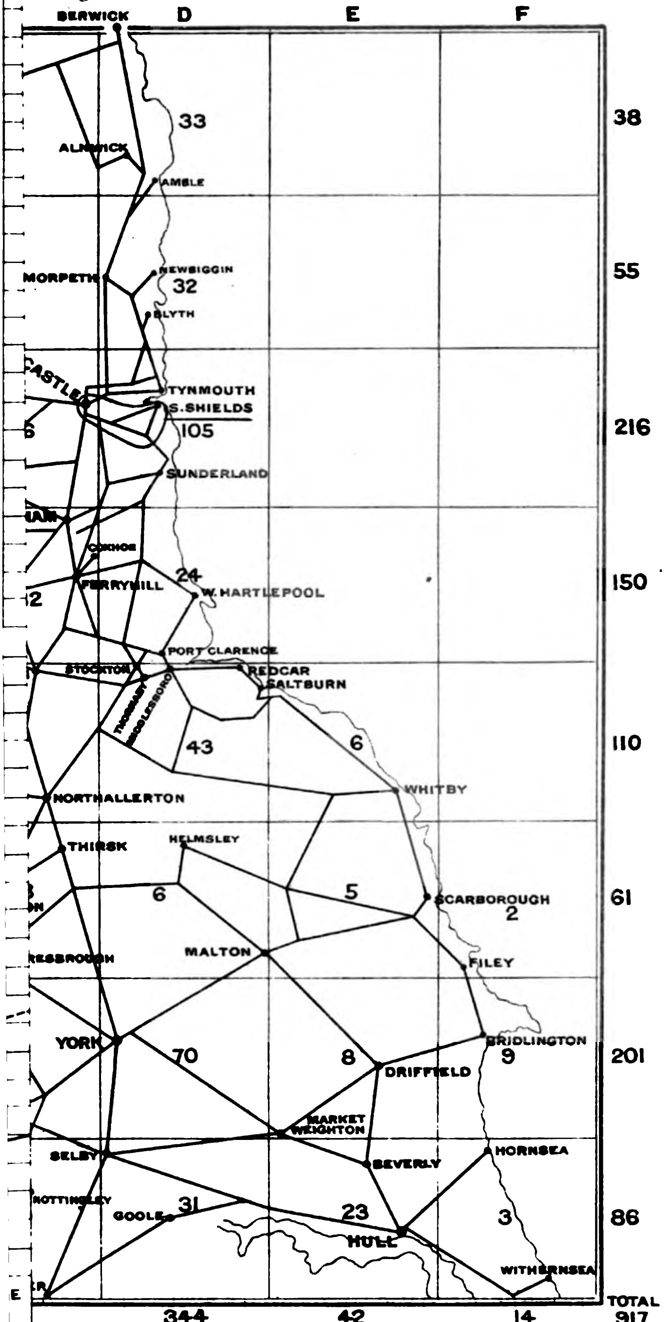
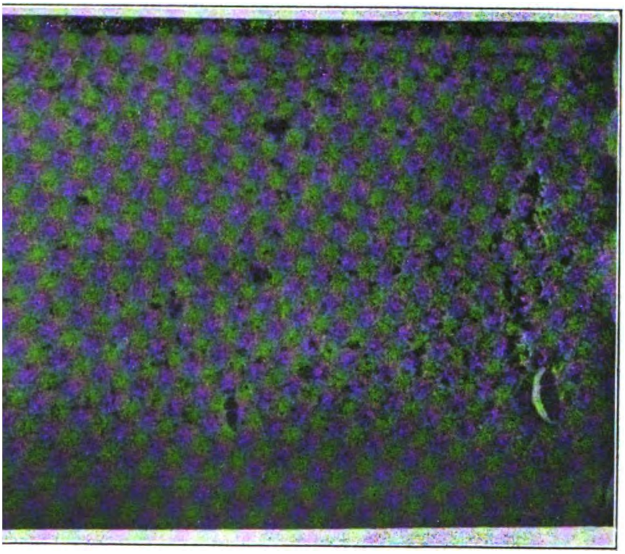


N OF THE NORTH EASTERN RAILWAY COMPANY

Fig. 5.



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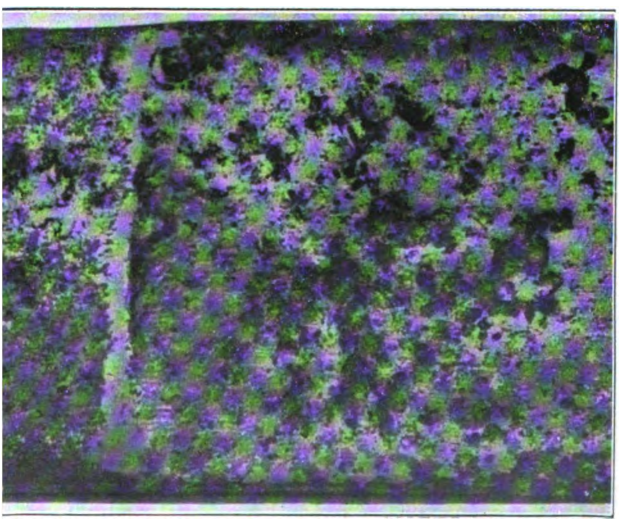

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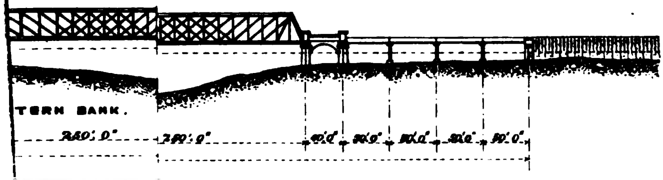

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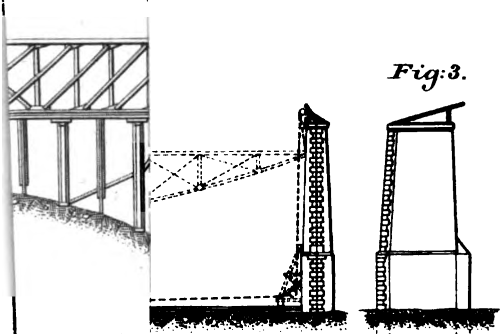

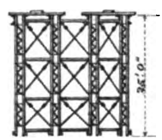

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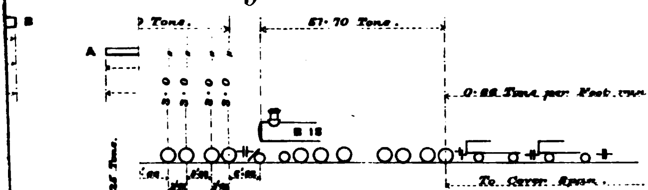

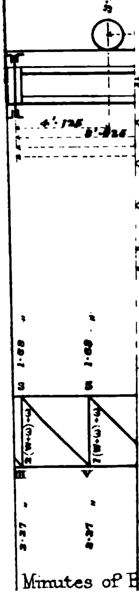

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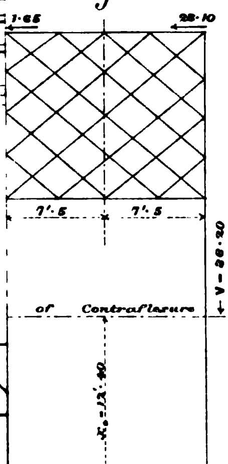
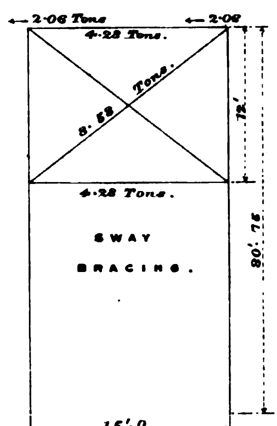


Fig: 17.



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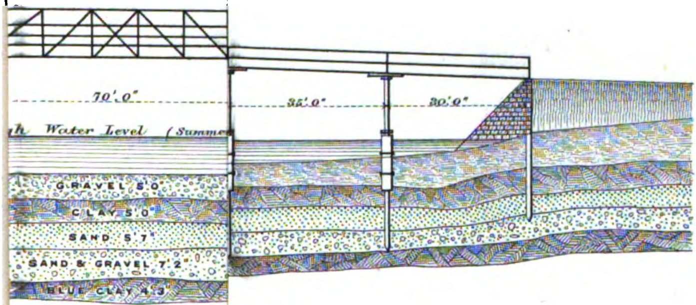
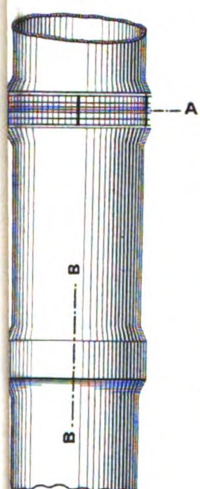


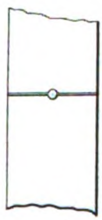
Figs. 4.



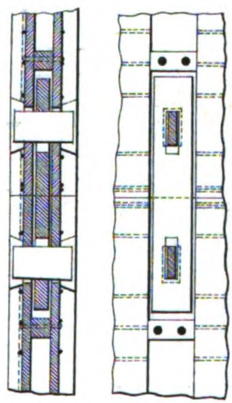
EVATION OF PIPE.

SECTION A A.

Figs. 7.



SECTION D D.



METHOD OF CONNECTING CYLINDERS.

— SCALES —

Fig: 1	*1 Inch*	=	*40 Feet.*
„ 2	*1 „*	=	*16 „*
Figs. 3 and 7	*2 Inches*	=	*1 Foot.*
„ 4, 5, 6, and 8,	*3/8 Inch*	=	*1 „*
„ 9	*1/4 „*	=	*1 „*

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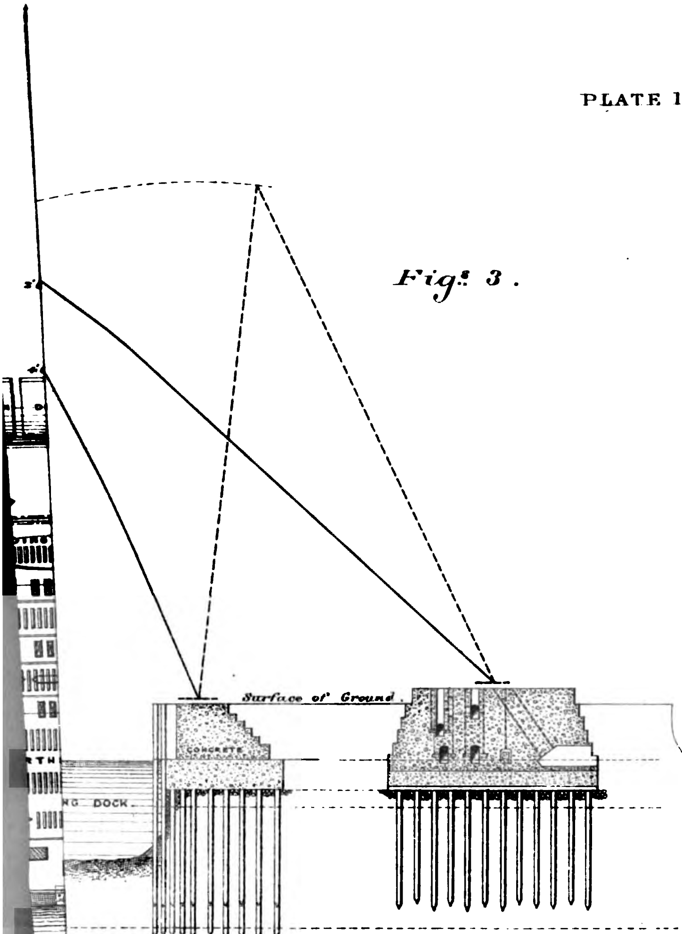
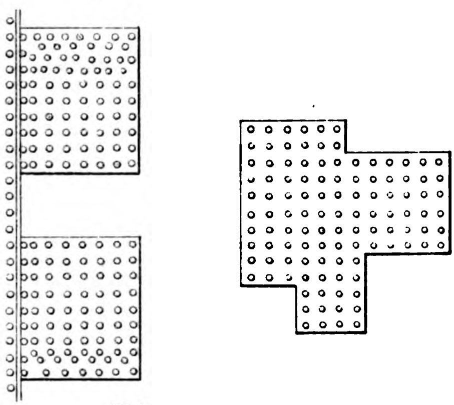
Figs. 3.



SECTIONAL ELEVATION.



PLAN OF PILING.

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